EXPERIMENTAL DIRECT SEEDING

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by the

FOREST SERVICE

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by

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Division of Forest Management
Research

Washington, D. C.

1940

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INTRODUCTION

A Planting Conference held in Region 9 in September 1938 brought out that considerable information was available on direct seeding at the forest experiment stations and that an effective exchange of such information would be helpful to the men studying direct seeding problems. Accordingly, all stations were asked to summarize past and current work into a progress report. Essential information given in these reports is here summarized. Also included in slightly briefed form are four of the more comprehensive station write-ups which give, better than any briefing could, the historical background of direct seeding and its possibilities.

The material submitted, which is approximately as of December 1938, was very heterogeneous, ranging from an almost telegraphic statement that administrative seeding had failed in the past, to several rather complete reviews of the past history, present studies, and future possibilities of direct seeding. It must be recognized, therefore, that this summary is not complete. The Stations undoubtedly had more pertinent data than was submitted, and developments since 1938, which have been very encouraging, are not included. This summary attempts to include what conclusions the stations were willing to draw from past work together with a listing of the factors being studied in current investigations. Direct seeding has had many ups and downs, unfortunately many of them downs, and information on how to seed with consistent success is still sketchy and inadequate. Blanks in this summary must be filled by more complete information on past and present work obtainable from the Stations, and by further investigation.

Also included in this summary is a suggested form, developed by Mr. Gordon D. Fox of Region 9, designed to provide a compact but complete case history of direct seeding trials. The form could be filled in by each station and copies distributed to all other stations. Comments are solicited on the worth-whileness of this suggestion and on modifications of the form.

SUMMARY OF PAST AND CURRENT WORK

Species

Conifers.

At one time or another a large number of coniferous species have been tested in direct seeding. Among those tested with varying success--or lack of it--in the various regions are the following:

Appalachian. Nonnative European larch, Norway spruce, Japanese larch, western white pine, Douglas-fir, Japanese red pine, and white spruce. Native Fraser fir, shortleaf pine, loblolly pine and Virginia pine. Practically no success was had with nonnative species.

(Over)

California. Trials or large-scale sowings have been made of ponderosa pine, sugar pine, Jeffrey pine, Douglas-fir, white fir, incense-cedar, and lodgepole pine.

Central States. Shortleaf, pitch, Virginia, loblolly, white, and red pines are included in current tests.

Intermountain. Douglas-fir gave good results but lodgepole pine, Sitka spruce, and western redcedar succeeded rarely in early tests. More recent attempts gave some success with western white pine, ponderosa pine, Douglas-fir, lodgepole pine, and Engelmann spruce.

Lake States. Jack pine has been tried with good success, and red pine, eastern white pine, ponderosa pine, Scotch pine, white and Norway spruce, arborvitae, European larch, and tamarack with less success. Jack pine's success is attributed to small size of seed, rapid germination, fast juvenile growth, and general seedling hardiness.

Northeastern. No direct seeding work but current studies of natural regeneration of red spruce and balsam fir will throw some light on direct seeding problems.

Northern Rocky Mountain. Western white pine, ponderosa pine, Engelmann spruce, and western redcedar have been fairly extensively tested with good success.

Pacific Northwest. Douglas-fir, Sitka spruce, western hemlock, and western redcedar are being tried.

Southern. Longleaf, slash, loblolly, shortleaf, and sand pines as well as "western pines and exotic conifers", Monterey pine, and Pinus longifolia have been tested without marked success.

Southwestern. Ponderosa pine, Douglas-fir, and western white pine have been experimented with more or less successfully.

Hardwoods.

The list of hardwoods is not so long as that of conifers. It includes yellowpoplar, black locust, black walnut, northern red oak, white oak, black oak, and southern red oak in the Appalachian region; shagbark hickory, northern red oak, black walnut, and yellowpoplar without success at the Central States; red oak, burr oak, basswood, white ash, black locust, butternut, sugar maple, and yellow birch with some good results with the oaks at the Lake States; red oak, black locust, white ash, black cherry, sugar maple and basswood with "generally disappointing" results at the Northeastern Station; red alder in the Pacific Northwest; and dogwood and "approximately 20 species" in the South.

Climatic Factors

Direct seeding and natural regeneration are very similar as regards the effect of climatic factors. Yet few definite studies of the effect of climatic factors on seed germination and survival of seedlings resulting from direct seeding seem to have been made and apparently not a great deal has been done to apply information gained from studies of factors affecting natural regeneration to direct seeding. Sowing on unfavorable sites, where successful natural regeneration could not be expected regardless of adequacy of seed source, was a major cause of failure in early seeding trials.

In the Appalachians, frost heaving has been cited as an important cause of loss in seeding with yellowpoplar, black locust, shortleaf, loblolly and white pine.

Old large-scale trials in California attributed failure of several species to drouth. Current tests which include careful measurements of individual factors may throw some light on this question.

Tests in the Intermountain region between 1912 and 1916 blamed drouth and frost heaving. Recent exploratory tests showed that surface soil temperatures are so high as to require the protection of the seedlings until the stems are suberized.

Studies at the Lake States have shown that dry periods during sowing or immediately following germination may be serious. High surface soil temperature is also important. Cold winter weather, because of protective snow cover, is ordinarily not serious. Frost heaving has occurred. On the Superior National Forest some recent sowing has been done on snow with some success; however, some loss has been blamed on the alternate freezing and thawing which seem to attend this practice, and as a result sowing as close to time of snow melt is advised.

Seeding trials at the Northern Rocky Mountain station have shown that drying of the soil below the depth of first season root penetration, as well as high surface soil temperature are important causes of loss.

In the South sowing in the rain did not result in a successful catch; and many of the other failures have been attributed to drouth.

Time of Sowing

Unfavorable conditions for germination can be avoided to some extent, as in the nursery, by careful selection of the time of sowing. With conifers, fall sowing has in most instances been found superior to spring sowing, because in the fall sowing can be done over a considerable period during which current soil moisture is not of upset importance, and because

fall sowing ensures that, as under natural conditions, seed will be in the ground all ready to go as soon as conditions are favorable in the spring. A disadvantage of fall sowing is that seeds are long exposed to rodent depredations. With spring sowing, though sometimes successful, the suitable seeding period is usually rather short and it is often difficult because of rain, mud, and transportation difficulties to get out into the woods early enough to sow successfully.

Both spring and fall sowing gave fair to good germination with hardwoods in the Appalachians. Both times of sowing are being tried in current tests with conifers in the Piedmont.

In California some of the early sowing at Feather River resulted in failure for both spring and fall sowing. In some cases spring sowing gave delayed and uneven germination, while fall sowing seemed to give generally better germination. Spring sowing is making a good showing, however, in a current study with ponderosa and Jeffrey pine.

Recent exploratory tests in the Intermountain Region show that fall sowing is better than spring sowing when effective protection against rodents is provided.

The Lake States station studies showed that fall sowing is useful for white pine and white spruce whose irregular germination is improved by cold stratification thus provided over winter. Fall sowing has the disadvantage of exposing the seed longer to birds and rodents. Spring sowing is usually favorable if the season is not too dry. Good results have been obtained by sowing just after the frost is out of the ground.

At the Northern Rocky Mountain station fall sowing is giving much better stocking than spring sowing in current studies.

A current study at the Southern station involves sowing in early winter, late winter, and spring.

In the Southwest sowing Sept. 15, Nov. 30, April 15 and June 30 showed no significant effect on results. Summer and fall sowing are being studied.

Site

Shirley (1937) effectively stated the importance of site in direct seeding as follows: "Except for swamps or particularly rocky sites, no area can be established to conifer forests by direct seeding, which cannot be planted successfully." To this might be added "or on which successful natural regeneration, given a seed source, cannot be expected." These limitations must be constantly kept in mind. Soil and vegetative competition are factors often blamed for failure, but others may also be important.

A failure of yellowpoplar seeding in 1923 at Bent Creek in the Appalachians was attributed to competition from "brush and briars."

In California, current studies have been designed to determine the effect of aspect and vegetation, and include the following--north aspect-cleared, partially cut, and virgin complete stand; and south aspect-cleared, and virgin complete stand.

Early studies at the Intermountain indicated that mineral soil with minimum competition gave best chance of success.

On the Nicolet Forest in the Lake States the height of the water table was shown to be an important factor. Soil should be moist near the surface. Studies further showed that loam, silt and clay are better in this respect than sands. North exposures and moist situations are favorable. Sands may, if moist, give good germination, but survival may be poor. As for competition, it appears that grass, sedge, herbs, and low shrubs are the most serious competitors for seedlings. Where such competition is not eliminated, failures have resulted. Only sandy areas with a low turf of blueberry, sweet fern, in clumps of scrub oak, or hardwood burns with sod or sumac, or practically barren areas should be considered. Even on these soils preparation is needed.

Current studies at the Northern Rocky Mountain station include tests of 1) recently burned north slope, 2) recently burned flat, 3) three-year old white pine plantation on old broadcast burned north slope, 4) sapling white pine on northwest slope, and 5) north slope with ceanothus and willow brush. These should provide helpful information.

In the Pacific Northwest, sowings on various aged burns showed more favorable results on the Olympic Forest on areas one or two years after fire than on older burns or unburned areas.

At the Southern station, a number of recent greenhouse studies on natural regeneration have produced results having a bearing on direct seeding. One study of soil surfaces which included 1) raw subsoil, 2) exposed surface soil, 3) various litter covers, and 4) ashes of various origins, gave "marked . . . and very striking differences" in germination, root penetration, and survival. Another study, of water supply, showed differences in rate of germination, but not in total germination, due to the amount of available moisture. A study of surface and subsurface wetting showed by analogy the inadvisability of direct seeding very wet sites to longleaf pine. Current field studies include trials of conifers on a "pine ridge", and a "hardwood draw"; and of approximately 20 hardwood species in a savanna in Mississippi. Another study of the relation of soil class to germination and root penetration showed that heavy soils were the least satisfactory for southern pines.

In the Southwest, studies of elimination of competition showed that best results came from removing soil to a depth of 2 inches to get rid of

weed seeds, and that growth of seedlings was better on scalped spots or untreated spots. Competition was also effectively reduced by removal of 4 inches and 12 inches of soil. Current studies involve sowing on denuded and open burns, burns stocked with oak, aspen, and locust; partially cut mature stands of Douglas-fir--white fir on north slope; mixed ponderosa pine, white pine, and Douglas-fir on south slopes.

Preparation of Site

Considerable attention has been given to various methods of site preparation such as stripping, scalping, cultivation, and burning. In discussing preparation of site, it is difficult to avoid some overlapping of material included under Site and Methods of Sowing. Consequently, some of the information given under this heading appears under the other two subdivisions.

At the Appalachian station failure resulted with yellowpoplar on "prepared spots" in which the seeds were covered with soil. White pine gave fair success on burned-over forest land where spots were "prepared" and the seed covered. Current studies include trials of shortleaf, loblolly, and Virginia pine with scarification, raking in the seed, and mulching.

In California in 1925 locally collected ponderosa and Jeffrey pine sown on a 1924 burn on the Lassen Forest gave excellent survival and growth on part of the area. Current studies designed to show the effect of site treatments include 1) stripped brush, 2) dug grass, 3) burned timber, and 4) burned and stripped brush. Burned timber is showing the best survival for all species.

At the Intermountain Station, recent exploratory tests showed that competition from brush, grass, and weeds must be reduced; this can be done by sowing on fresh burns, skid trails, and burned brush pile sites. Current tests are being made of variations in width and depth of scalping.

In the Lake States, it was found that disking made possible the successful broadcasting of jack pine. Broadcast sowing without some preparation was found impossible. Disk harrows and spring tooth harrows have been used with good results. Scalping is a satisfactory method of eliminating competition during the first season. Burned areas, if sowed immediately, may be successful. This opens up the possibility of preparing areas for sowing by burning under controlled conditions.

The Northern Rocky Mountain station is currently studying sowing on clear-cut and broadcast burned areas within a year after burning. Tests are also being made of cultivated and uncultivated spots.

At the Southern Station trials were made in Florida of 1) soil spaded, 2) fresh burn, 3) disking, 4) one year rough, 5) three year rough,

and 6) four year rough. All were good "with significant differences in favor of reduction of the rough."

In the Southwest early studies showed the need for bare soil and removal of competing vegetation. More recent studies were made of mixing various materials with the soil, and of top dressings. Duff, "serval", and peat moss should not be mixed with the soil; mixing of decomposed organic matter with the soil was effective, and a top dressing of duff was good. Current studies are being made of ammonium phosphate, ammonium sulphate, and "Vigoro" mixed with soil to a depth of twelve inches. Studies are also under way on the effect of litter of ponderosa pine, white pine, oak, and aspen on broadcast sown spots. Another interesting current study involves combinations of scalping, covering seed with duff, weeding during the growing season, and spading the soil before sowing; scalping the vegetation and covering the seed to a depth of 1/4 inch gave best results; covering with duff was helpful in dry years; spading before sowing was not helpful.

Methods of Sowing

In the Appalachians, broadcast sowing of black locust, shortleaf, loblolly, and white pine, failed; spot sowing failed also, where seed was not covered, and even where covered on denuded and eroded land. On one area a road ripper was used to prepare the soil and the seed was drilled in; no results of survival are given.

In 1909-1910 in California broadcast sowing on ground and snow without covering the seed, with raking, and on prepared spots with covering, and sowing with a corn planter were all unsuccessful. Later, 1912-1916, prepared seed spots were sown with 10-20 seeds per spot and covered to a depth of 1/3 to 1/2 an inch with soil.

In the Lake States, broadcasting in furrows and scalps and pressing the seed in with the feet was wasteful of seed. Rakes and hoes improved results. Use of 1/4 inch groove in a spot with 6-10 seeds, and closed firmly, has given good results. A garden drill has proved useful in plowed furrows. Broadcast sowing on fresh burns has been successful in several instances.

The Northeastern station has a current study which includes 1) placing seeds at bottom of shallow slit in sod; 2) lifting small scalp of sod, placing seed at the end of exposed soil, and replacing sod; 3) removing scalp of sod and placing seed at edge of scalp; and 4) placing seed in spots in furrows made with a Syracuse forestry plow. The results have so far been generally disappointing.

A current study at the Northern Rocky Mountain station includes 1) mineral soil tamped, 2) mineral soil untamped, 3) ashes tamped, and 4) ashes untamped. No differences are apparent yet.

In the Pacific Northwest, broadcast seeding on the Olympic Forest on moist areas has been successful but not consistently so.

Broadcast sowing, spotting, and sowing in furrows were tried in the South.

From the variety of sowing methods tested and the often inconclusive nature of the results, it seems reasonable to conclude the method of sowing must be varied to suit particular conditions and that in many instances most suitable methods have not yet been devised. It has been quite generally found, however, that broadcast seeding is both wasteful of seed and uncertain of results. The trend is toward seed spotting as a generally more economical and successful method.

Seed

Seed quality is one of the most essential factors in the success of direct seeding, but seems to have been almost neglected until very recently.

In California current studies are designed to show the influence of elevational origin, parent tree characteristics, and size of seed. Methods of storage and pre-treatment are also being studied.

Recent exploratory tests at the Intermountain station showed that only about 50 percent of clean, sound ponderosa pine seed will germinate under field seeding conditions. This would seem to indicate a need for emphasis in seeding studies.

Poor germination has been experienced in the Lake States when seed has not been pretreated. Cold stratification has been shown to be desirable for at least white pine and white spruce. Studies on rate of sowing showed that 4 ounces of high quality jack pine per acre should give satisfactory stocking in a favorable season.

The Northeastern station has a current study which includes overwinter cold storage, stratification in peat moss, removal of outer hulls of basswood before stratification or cold storage, pre-sprouting red oak, and inoculation of black locust. Detailed studies are also being made of basswood seed treatment. The results have been generally disappointing.

In a study at the Northern Rocky Mountain station, low germination percent of seed used was an upset factor in determining significance of treatments. Development of a reasonably accurate, quick viability test is rated as an urgent need. Stratification of western white pine seed in moist sand seven weeks before sowing is being tried.

In the South, a trial was made of bringing seed to the point of sprouting before sowing, but without successful results. Moist cold stratification of slash pine seed gave better germination than unstratified seed.

In the Southwest, pretreatment of seed to get partial germination before sowing is being studied. There seems to be prospect of success when pregermination is not allowed to advance too far. Current studies are being made of dates of sowing. Past studies have shown that within a species, seeds larger than average have given best results.

Protection

Destruction of seed by various birds, rodents, insects, and animals has been almost universally a major problem in direct seeding. Good seed, when properly planted on favorable sites, will come up and grow. Again and again, the biological factor has been the cause of failure and a good share of direct seeding investigations has revolved around ways and means of circumventing the seed eaters.

Before discussing methods of protection, however, it will be helpful to know which are the chief offenders. Mice, chipmunks, red squirrels, and seed-eating birds have been caught in seed-baited traps in the Lake States. In the Northern Rocky Mountains, mice seemed to be the chief seed eaters. In the Pacific Northwest, white-footed mice, shrews, Gibbs moles, and chipmunks were trapped by using Douglas-fir seed bait. In the South ants (*Cremastogaster lineolata*) were serious causes of destruction of longleaf pine seeding. The Biological Survey showed that a number of seed-eating song birds are responsible for serious losses. The worst offenders in southern Mississippi were the meadowlark, mourning dove, bobwhite, and 4 species of blackbird--cowbird, rusty blackbird, Brewer's blackbird, and red-winged blackbird. The bird factor was apparently serious enough to cause Burleigh (1938) to say: "Direct seeding should not be undertaken (in southern Mississippi) during years when seed is produced in abundance. Maximum natural survival can apparently be obtained when the cone crop is light and birds are relatively scarce. Best results from direct seeding can also be expected during such years." In the Southwest, cottontail rabbits and juncos are important culprits. Damage from deer has been reported by the Appalachian, from cattle by the Intermountain and Southwestern, and from horses by the Central States.

A great variety of methods have been and are being employed to minimize seed depredations. They fall into four general classes: screens and other physical barriers; repellents; poisons; and various rodent "deceivers"--i.e., attempts to disguise or otherwise hide seed.

Screens and other physical barriers.

Current studies in California involve use of chain mesh rodent wire fences surmounted by strips of sheet metal to keep rodents out of experimental plots. The mesh goes into the ground 6 inches. This is only partially successful, and must be supplemented with screens over the seed spots. Cones of 4 mesh, 20 gauge wire screen, galvanized after weaving,

are cut from hardware cloth 42 inches wide in semi-circles of $10\frac{1}{2}$ inches radius. Eight cones can be cut from a yard of cloth. The cone is laced together with 20 gauge soft wire. The material costs about 11¢ per cone. Such cones reduce the maximum (surface soil?) temperature 2°-5° F. The cones must be removed at the end of the first season of growth.

Recent exploratory tests at the Intermountain station showed that small window screen tubes are unsatisfactory, that hardware cloth cylinders or cages are not recommended; and that 1/3 inch (3 x 3) mesh hardware cloth cones give good results. Current studies include further tests of size of cones, time of removal, and use of cotton netting.

In the Lake States, best results were obtained from 2- or 4-mesh galvanized hardware cloth cones which can be used several times. Some of these cones have been in use for 11 years.

At the Northern Rocky Mountain station, screen cones made of 2-mesh hardware cloth were found effective but too expensive for administrative application. The cones also shaded the seedlings to some extent giving a certain amount of protection from heat injury.

In the South, studies are under way on comparisons of wire tubes and cones.

At the Southwestern station, it was found that survival was higher under screen protection; that there were no differences between $\frac{1}{4}$ and $\frac{1}{2}$ inch mesh screens. A study is being made of time of removal of screens involving use of cans in combination with screens. Other physical barriers receiving attention include cellophane "deflectors," transparent and translucent, in the form of cylinders. These raised the temperature around the seedlings as much as 25 F. and are not recommended.

Repellents.

The Appalachian station has asked the Biological Survey to undertake studies to find "natural or synthetic animal odors that might induce a fear reaction, such as snake or weasel scents. . . (The material) must be available at reasonable cost, and when applied must retain its strength in the field for several weeks." This is really a phase in which help of specialists is needed. No success has been had with any of the numerous repellents tried.

California reports that early trials of coating seeds with repellents were ineffective. The Lake States station found that sulfonated linseed oil on seeds and soil was only slightly beneficial. In the Northern Rocky Mountain region commercial preparations such as "No Crow", "Bye Bye Blackbird", and "Crotox" were all found ineffective. The Southern station tested various rodent repellents in a rat-infested garret in New Orleans, and the only ones effective against house rats were a few like wood creosote that

were lethal to longleaf. "Sulphanol" was also tried, but was ineffective against house rats. In 1909 in the Southwest, red lead, blue vitriol, and creosote were ineffective. A commercial preparation, "Rodopel", did not deflect rodents. A number of other repellents have been tried, for example, at the Central States station, but no results were sent in, and hence their experience could not be included.

Poisons.

Early in California, 1910-1911, poisoning prior to sowing on large areas on the Shasta Forest failed to effectively reduce rodents. Between 1912-1916 areas around Feather River were poisoned liberally with grain baits, but without success. More recently, poisoning an area intensively, before sowing, with thallium was most effective, but even this gave incomplete control, and there are serious objections to the extensive use of thallium.

In 1925 Wahlenberg reported a successful seeding on the Lolo Forest, and attributed the good results in part to using red lead on the seeds and scattering poisoned oats.

The Lake States found red lead dust to be only slightly beneficial, while the Southern station found it ineffective.

The Northern Rocky Mountain station is using a coating made up according to recommendations of the Biological Survey Control Methods Laboratory: 48% yellow dextrine, 31% plaster of paris, 15% yellow corn meal, and 6% strychnine alkaloid. This mixture forms a persistent coating even when wet. Sunflower seed coated with thallium sulphate has also been spread around areas to be seeded as a pre-seeding rodent eliminator. Combined use of these two poison treatments has been very successful and are being further tested. This method is also being tried at the Southwestern station.

A pertinent consideration in the use of poisons is that they cannot be adequately or fairly tested on small areas of 3 or 4 acres or so. The rodent population may be sufficient to destroy the seed by sheer force of numbers despite the poison. The Northern Rocky Mountain station believes that seeded areas should be at least about 20 acres to give a fair test of the poison method. Much of their success with poison is attributed to its application over fairly large areas.

Rodent "deceivers."

Several attempts have been made at the Lake States station to disguise seed spots by using grass, leaves, sticks and other material. This was only partially successful, decidedly inferior to screens, but better than no protection. In 1935 the Southern station tried covering spots

with broomsedge in heavy and light layers, and with a light layer of longleaf needles. The heavy broomsedge was best but had to be removed in several operations.

Another principle used at the Southern station was trying to render the seed unfamiliar to rodents. The seeds were placed in gelatin capsules, which dissolved in water too quickly to be effective. Seeds were also placed in agar in wire tubes but there was some difficulty in moisture supply.

In summarizing the results of various protective measures, screens have generally been found effective and have the added advantage of offering some physical protection to the seedlings. Though useful in experimental development of direct seeding, screens have the so far fatal administrative disadvantage of too high cost for extensive application. No really cheap screen that can safely be left in place has yet been developed. Screens of heavy hardware cloth which have been most used must be removed within a year or two after seeding, and though they can be used over again, the cost of gathering them, handling, storing, and re-using is considerable. No satisfactory chemical repellent has been found, though many have been tested. Poisons offer considerable promise of success; it seems that about the only sure-fire way to eliminate seed eaters is to kill them. Poisons must be used with much care, however, and methods must be adapted to the particular region and kind of predator. Rodent "deceivers" have not been so far successful, though it is possible that some such imaginative scheme may work in certain localities.

Later Care

The Lake States station concluded that no special care appears to be needed when site preparation has been adequate. Weeding is often found to be necessary in the second year. Thinning may be advisable the third year, and if done carefully, the seedlings removed can be planted in fail spots. Furrows usually require no weeding. As in the case of planting, this question of later care should not be overlooked. In general, however, it seems that needs for later care, which inevitably will cost money, should be kept to a minimum by focussing attention on getting a satisfactory "catch" in the first place.

Costs

E. E. Carter, in commenting on a note by Maki in a recent Planting Quarterly, says in part, "Maki . . . hits the nail on the head. The final costs measured in terms of acres of successfully stocked land are the real criteria. Unfortunately, past results indicated that, except on fresh burns where the rodent menace had been removed, direct seeding results on that basis cost more than planting. If he can develop methods to change that relationship, God bless him. We'll grab for them."

This makes it abundantly clear that in our attempt to learn how to direct-seed, our best customer--the National Forests--will rightfully insist that we develop methods cheaper than planting. The following table taken from the Nov. 1, 1939, issue of the Planting Quarterly gives a rough guide to the upper limit of cost per satisfactorily stocked acre that could be incurred by direct seeding.

Increased Average Cost per Acre due to Losses in Plantations
Averages of the 5-Year Period, 1934-38

Region	Initial Cost	Additional Cost Due to Losses: Aver. Reg'l Loss	Additional Cost Due to Losses: Amount	Total Cost
	Dollars	Percent	Dollars	Dollars
2	12.86	43	5.53	18.39
4	18.25	..	..	18.25
7	15.72	14	2.20	17.92
5	15.31	17	2.60	17.91
9	10.71	47	5.03	15.74
1	12.28	18	2.21	14.49
6	9.41	15	1.41	10.82
8	7.23	6	.43	7.66
ALL	..	32	..	..

This table does not, strictly speaking, give the cost per satisfactorily stocked acre because it is based on the 5-year average initial cost (stock, preparation, planting) plus the percentage of "lost" plantations. Thus Region 2 "lost" 43% of all plantations, so that 43% of $12.86, or $5.53 gives a total cost of $18.39. An important factor in this question is the definition of a "lost" plantation. It varies by regions; a plantation is lost when it has less than 60 surviving trees per acre in some regions to less than 250 in others. The standards for direct seeding should not be any lower than for administrative planting.

The information sent in on costs of experimental direct seeding was not voluminous, and because a wide range of conditions is represented the significance of the figures is difficult to interpret. In the Black Hills, in 1909-1910 costs varied with ground preparation and methods of sowing: $31.66/acre for careful spots, $12.00/acre for "modified" spots, $5.50/acre for furrows, $1.50-3.80/acre for corn planter, and $2.05-$2.65/acre for broadcast sowing using 4 pounds of seed per acre. In 1925 a successful seeding was reported on the Lolo Forest at a cost of $6.31/acre.

Costs on the Superior Forest including ground preparation ranged from $26.85/acre for broadcast sowing to $12.35 for spot sowing. The Forest Staff believes, however, that costs could be reduced to $10/acre.

The Lake States station helpfully expresses cost on a comparative basis. The costs of soil preparation for seeding are the same as for planting; sowing on scalped spots takes less labor than planting; screening increases the cost to equal that of planting; drilling with machine in furrows can be done at the rate of an acre per man hour; seed costs are high; and direct seeding judiciously done, can cost between 1/3 and 1/2 that of planting.

Basically, direct seeding, once successful methodology is worked out should be as cheap or cheaper than planting. The actual operation of sowing is no more complex or difficult than planting. The cost of seed and poisoning or other pre-treatments necessary, should be less and certainly not exceed the cost of nursery stock production, especially when it is considered that nursery production must be rather rigidly scheduled 2 to 4 years in advance of actual planting. Direct seeding is more flexible in application.

Outlook

The outlook for direct seeding is well given in the words of T. E. Maki. The reader can substitute his own geographic and species names for Intermountain equivalents and the paragraphs will in general apply to his region.

"It is unfortunate that the severe setbacks of the early years resulted in complete stagnation of thought and effort in the field of artificial reseeding; it resembles still pretty much of a trackless sea with progress in charting safe courses intolerably delayed by the pioneering failures. Today there is so much to do and so little with which to begin. Enough has been found in recent tests to encourage further work, but it is not at all certain that the present lines of investigation are heading directly to the most effective technique. One thing appears certain already, namely that for ponderosa pine in Central Idaho the successful way does not lie in the direction of promiscuous scattering of seed but rather in fewer seed more adequately hidden from rodents, and more fully protected from heat and drought during critical periods. One needs only to consider the arithmetic of Nature to realize what tremendous odds seeds and seedlings have to overcome. For example, in the Pine Creek area of the Boise Basin, combined measurements and estimates by seed traps indicated a mean seedfall of 307,000 seed per acre in selectively cut stands of ponderosa pine. This is equivalent to more than 36 pounds per acre! This amount of seed resulted in a mean germination of 5,052 seedlings per acre, of which only 558 seedlings survived at the end of the first year! Five hundred and fifty-eight 1-year-old seedlings per acre cannot be considered a satisfactory catch in central Idaho. Nature attempts to offset the effects of heat, drought, and predators by sheer force of numbers, but man cannot hope

to, should not want to, emulate such an egregious practice, such a gross technique. He must resort to craft and cunning, to skill and guile.

"Numerous possibilities remain unplumbed. The tests described in this report represent rather crude, cumbersome, and costly methods. It is probable that seeding will always involve some "strong-arm" practices, particularly in the site preparation phases. But there are still the relatively unprobed avenues of fertilizing, repellents, of pretreated or pregerminated seed, of local poisons, yes, even the "much-maligned" agar pellets. These alone or in various combinations with mechanical devices may turn the trick. And there is always the very real possibility that a method that works beautifully under the dry summers and coarse, acid, granitic soils of central Idaho may fail completely in the heavy alkaline soils and the comparatively abundant summer rainfall of Utah. At this stage no seemingly harebrained idea should be entirely condemned, no criticism contemptuously ignored. Nor should it be considered that in the Intermountain Region seeding has been given the same opportunity as planting. Neither are as yet satisfactory; both should receive a fair and adequate trial."

Where does all this leave the problem of direct seeding? A great many species of methods have been tried over the years stimulated by a deep and persistent feeling that the method has real possibilities once some knotty problems in methodology are worked out. Direct seeding has certain solid advantages in greater flexibility as to time and place of planting--no bulky planting stock to transport, directness in application; no advance nursery production scheduling necessary, permitting prompt action in emergencies as in quickly reforesting large burns; and genuine possibilities of achieving low cost. There have been many seeding failures but some notable successes to spur on further effort.

Recent developments at the various stations give definite encouragement that at long last consistently successful seeding methods will be developed which will make the method a valuable adjunct to planting.

There have been three major obstacles to successful direct seeding: rodents and other seed eaters, unfavorable physical site factors, and cost. No method can hope to be consistently successful that does not provide for protection against rodents and other seed eaters. Progress has been made on this problem; at present poisoning methods seem to offer the best possibilities because of low cost. Screens are generally effective but so far the cost has been too great for general application. Repellents have not been successful.

The problem as regards unfavorable physical site factors seems to be quite largely one of acquiring a more thorough and specific knowledge of climatic, soil and other factors under which seed can be expected to germinate and seedlings grow successfully, and avoidance of unfavorable sites. Much of the "black eye" acquired by early seeding trials was acquired by attempting reforestation on sites where seedlings didn't have a chance to survive.

Finally, the problem of cost must be squarely faced. No method can be widely employed unless its cost can at least equal or preferably considerably underrun planting costs, all factors considered. It does seem, however, that the first problem is to find out how to seed with consistent success. Once this has been worked out, ways and means can probably be developed to cut costs to a reasonable figure. Such has been the history of many a development; first find out how to do it and then how to do it cheaply.

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REGIONAL PRESENTATIONS

DIRECT SEEDING EXPERIMENTS IN CALIFORNIA

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1. Past Work

Early Administrative Seeding. Direct seeding as a means of reforesting burns and waste areas received the attention of foresters in California as early as 1904. According to S. B. Show (MS 1/15-17), P. D. Kelleter and Wm. Hubbard experimented with pine seed scattered on cut-over and burned land near McCloud, Shasta National Forest, in 1905 and 1906. Beginning about 1908 seed of many conifers were sown in numerous brushfields by administrative officers on several forests. Under the direction of N. O. Torstensen on the Shasta, 36 acres were sown to ponderosa pine and 18 acres to sugar pine in the fall of 1909 and spring of 1910 in the vicinity of McCloud. In the fall of 1910 additional sowings were made on 60 acres in one location and unstated acreage in another location. In these early sowings the seed was broadcast on the ground and on snow without coverage, or was covered by raking. Coverage in prepared seed spots and the corn planter also were tried. The sowings were uniformly unsuccessful, failure being attributed to seed-eating rodents.

First efforts to control rodents seem to have been made at the time of the fall sowing in 1910, when the seed was coated with repellents and poisons. These efforts were ineffective.

Cooperation of the Biological Survey was sought in 1911, and between September and November of that year S. E. Piper, of the Bureau, attempted to eliminate the rodents from two large areas by intensive poisoning prior to sowing. Examinations in the early summer of 1912 showed that rodent damage was not effectively reduced. The seedlings, which appeared in a few places, died during the hot dry weather of summer.

Almost uniform failure of these first attempts caused discontinuance of administrative direct seeding after a small amount of sowing on the Sisson burn in 1912. With production of the first transplants at Pilgrim Creek Nursery in November 1911, attention was directed toward planting.

Feather River Experiments, 1912 to 1916. Beginning in the fall of 1912 a series of experiments with direct seeding were begun at the newly established Feather River Experiment Station in the Plumas National Forest. The last sowings were made in the spring of 1915 and last examinations were made in the fall of 1916.

The sowings were made in two locations, the open alluvial flat at 3500 feet at Feather River, and the brushy slopes at about 5000 feet near Bear Creek Ranger Station. Probably there was no advance treatment of the site. Sowings were made in October 1912 and May 1913 at Feather River, and in the fall of 1914 and spring of 1915 at Bear Creek for most of the species tested. The species tested were ponderosa, Jeffrey, and sugar pines, Douglas-fir, white fir, and incense-cedar. Each test included 100 prepared seed spots in which 10 to 20 seeds were sown and covered to a depth of from 1/3 to 1/2 inch with soil. In the fall tests at Feather River, from 15 to 18 of the spots in each test were screened against rodents. The spring tests were unscreened. At Bear Creek the spots apparently were not screened, but the spots and surrounding area were poisoned liberally with grain baits. Twenty-one trials including 2100 seed spots are recorded in all. Failure is reported uniformly as the result of these tests.

In the open Feather River location, where rodents were few, germination from fall sowing was good for ponderosa and Jeffrey pines and for Douglas-fir. The seed lots of the other species were poor. Spring sowing resulted in delayed germination for all species, the total for first and second spring seedlings usually being less than for fall sowing. Practically all the seedlings which appeared were dead after the first summer. Mortality was attributed to drouth.

In the Bear Creek brushfield, rodents took practically all the seed before germination. The few seedlings which appeared were practically all dead by the fall of 1916, death being attributed to drouth.

Pilgrim Creek and Feather River Nursery Experiments. Between 1910 and 1920 at Pilgrim Creek and between 1912 and 1917 at Feather River, in the course of nursery experiments, many facts bearing on direct seeding were learned. Experience was gained in the collection, separation, and storage of seed, germination to be expected, favorable times for sowing, depth of coverage, shade requirements, and frost hardiness of the several important species. Much of this experience was included in file reports and in U.S.D.A. circular No. 92 by S. B. Show.

Recent Administrative Seeding. The nearly uniform failure of all attempts at direct seeding between 1904 and 1917 convinced most administrative and research officers of the futility of this procedure under the prevailingly adverse site conditions of northern California. Administrative planting was resumed in the fall of 1929 after establishment of Susanville (now Durbin) Nursery in 1928. Several severe burns on good timbered sites had occurred and suitable nursery stock was not immediately available. The desire to prevent seizure of these burned soils by brush led to further attempts at direct seeding.

About 9 acres were seeding in November 1925 on the 1924 Antelope burn, Lassen National Forest, by A. E. Wieslander. Local ponderosa and Jeffrey pine seed was sown in spots resulting in excellent survival and growth on a portion of the area.

In 1929 two acres, and in 1930, four acres were sown to sugar pine on a burn in the Sierra National Forest. In 1930, eight acres were sown to ponderosa pine on the Sugar Hill burn, Modoc. No further seeding was done until the fall of 1934. The sowings from 1934 to 1937 are summarized as follows: Most of these sowings were in seed spots.

Date	Forest	Location	Site	Species	Acres
1934	Eldorado	Middle Creek	Timber burn	Mixed	80
	Lassen	Big Spring	Stripped brush	PP	20
	Lassen	Big Spring	Stripped brush	JP	30
	Stanislaus	Anderson Va.	Timber burn	PP	64
	Stanislaus	Anderson Va.	Timber burn	JP	130
	Stanislaus	Anderson Va.	Timber burn	IC	18
1935	Eldorado	Middle Creek	Timber burn	SP	20
	Eldorado	Middle Creek	Timber burn	Mixed	67
1936	Sierra	Whiskers Burn	- - -	Mixed	273
	Tahoe	Forest Hill	Timber burn	PP	1367
	Tahoe	Forest Hill	Timber burn	JP	175
	Tahoe	Forest Hill	Timber burn	SP	186
1937	Tahoe	Forest Hill	Timber burn	PP	193
	Tahoe	Forest Hill	Timber burn	JP	91
	Tahoe	Forest Hill	Timber burn	SP	25

The Eldorado and Lassen sowings are reported as failures. The Stanislaus seeding in Anderson Valley is believed to have been successful. Results for the more extensive sowings in 1936 and 1937 are not yet available. Information on these projects may be found in the annual planting reports for Region 5.

2. Present Experiment Station Studies

Studies of direct seeding now in progress at the Experiment Station fall into four groups with respect to objectives, (1) response of seedlings to measured physical site factors; (2) response to site treatments; (3) the effects of rodents and means for rodent control; and (4) the influence of seed source.

Site Factors. The site factor study is mostly confined to Stanislaus Branch where conditions are favorable for sugar pine, ponderosa pine, white fir, and incense-cedar. The altitude is about 5000 feet. Five site-factor stations were established between 1931 and 1934. These stations

represent (1) north aspect, cleared; (2) north aspect, partial stand of sale area; (3) north aspect, virgin complete stand; (4) south aspect, cleared; (5) south aspect, virgin stand.

The stations are about 50 feet square. They are fenced with chain-mesh rodent wire extended into the ground 6 inches and surmounted with strips of sheet metal. The fences are only partially effective and supplemental screens over seed spots have been necessary.

The following observations are taken covering the growing season, usually from about March 1 to November 30:

Air temperature.		Continuous record.
Relative humidity.		" "
Wind movement.		Daily total.
Evaporation.		" "
Precipitation.		" "
Soil temperature,	1/4 inch depth.	Continuous record.
" "	1/4 " "	Daily maximum & minimum.
" "	3 " "	" " " "
" "	7 " "	" " " "
" "	12 " "	Read daily at 8 a.m.
" "	18 " "	" " " " "
Soil moisture, 4 depths to 21 inches.		Every 10 days.
Germination, fall sown seeds, SP, PP, WF, and IC.		
Mortality of seedlings by causes.		Daily during early stages.
Growth in height of seedlings.		Every 10 days.

In addition to these regular observations, wilting points and mechanical analyses have been made for the soils at the five stations. Seedling root penetration and rate of growth, and root regeneration after wounding and transplanting are being studied. The seasonal march of radial and height growth of established trees is being measured at 10-day intervals for ponderosa pine at 2000, 3000, 4000, 5000, and 6000 feet and for sugar pine, Jeffrey pine, lodgepole pine, white fir, and incense-cedar at 5000 feet.

At Feather River Branch seasonal growth studies are being made for ponderosa pine, sugar pine, Douglas-fir, and incense-cedar at 3500 feet. At Blacks Mountain Branch similar studies include ponderosa pine and Jeffrey pine at 5600 feet.

Site factor stations have been maintained during seeding experiments at Big Spring, Burgess Spring, and Burney Spring, Blacks Mountain Branch. Year-long weather records are maintained at branch headquarters at Feather River, Blacks Mountain and Stanislaus.

Site Treatments. Between 1934 and 1936 small groups of seed spots were sown in connection with planting experiments in locations where the brush cover and soil surface had been treated in various ways. These sowings followed no formal design, being purely exploratory. A brief summary

of these sowings follows. Only those seed spots screened against rodents are included. In most instances germination was good. The screens were removed at the end of the first growing season exposing the seedlings to rabbits and other rodents.

Date	Branch station	Cover	Treatment	Seed Spots PP	Seed Spots JP	Seed Spots SP	Seed Spots WF	Survival PP	Survival JP	Survival SP	Survival WF	Years
2/34	Blacks Mountain	Brush	Stripped	56	65	..	..	48	75	..	..	4
11/34	Blacks Mountain	Brush	Stripped	200	200	..	..	45	30	..	..	3
11/35	Blacks Mountain	Brush	Stripped	500	500	..	..	7	13	..	..	2
10/34	Feather River	Grass	Dug	590	171	63	..	48	39	48	..	2
10/34	Stanis- laus	Brush	Stripped	83	..	392	127	43	..	46	4	2
10/34	Stanis- laus	Timber	Burned	340	40	40	40	79	87	70	65	2
10/36	Blacks Mountain	Brush	Burned & Stripped	500	500	..	..	59	79	..	..	2

Results of these seed spot trials were very similar to results obtained by planting 1-1 nursery stock at the same places and times.

In 1937 two formal experiments were established in the Burney Spring brushfield, Blacks Mountain Branch. The two experiments have the same design. One was established in the spring, the other in the fall. Each experiment contains 5400 screened seed spots as well as 5400 nursery grown 1-1 trees. The intended comparisons are as follows: ponderosa pine and Jeffrey pine; seedlings and planted stock; brush cover burned, stripped, and burned and stripped; trees sprayed with rabbit poison and trees not sprayed.

Weather records are maintained at the site during the season of growth. The soil under the three brush treatments is sampled for moisture content at 10-day intervals. The wilting points have been determined directly. Root penetration has been determined at 10-day intervals.

Copies of the working plans for these studies have been exhausted. Additional copies can be made for anyone interested.

Latest examinations were made about October 20, 1938. Complete summaries are not available, but the following general means for survival are of interest:

	Seed spots		Planted stock	
	PP	JP	PP	JP
Spring 1937	75	84	83	90
Fall 1937	28	62	21	26

At the present time neither the seedlings nor the planted stock are safely established. As the brush cover returns, rabbit clipping becomes more severe.

Effects of Rodents and Means of Rodent Control. Rodent control has long been recognized as a prime requisite for direct seeding. Studies concerned with other factors in the field, as well as extensive seeding, are prevented by small seed eaters. Between 1926 and the present, numerous small tests have been made to find some effective means of excluding mice and chipmunks without seriously changing the physical factors of the study sites. Mr. E. E. Horn, of the Biological Survey, who was assigned to the Station July 19, 1928, has coöperated in Station studies and has conducted studies independently. Numerous repellents, poisoned baits, poisoned seed coatings, poison sprays on seedlings, fencing, and screening spots have been tried. Burning off the brush cover, sowing at different seasons, sowing by different methods, and attempts to find unpalatable species also have been tried. No measures have been found to give the nearly complete control necessary for undisturbed experimentation.

Poisoning the site intensively, in advance of sowing, with thallium appears to be the most effective method of eliminating the seed eaters. Even by this method, control is not complete. Serious objections to thallium poisoning have prevented its use extensively.

A seed spot screen has proved fairly effective for use in experiments. These screens are made from 4 mesh, 20 gauge wire screen, galvanized after weaving. Hardware cloth 42 inches wide is cut into half circles with $10\frac{1}{2}$ inch radius. Eight screens can be cut from a yard of hardware cloth. The circles are bent into the form of a cone and the slanting edges are laced together with 20 gauge soft wire. The cost for material is about 11 cents a screen.

The base of the screen is worked into the soil around the seed spot to a depth of about 2 inches. A special tool was made for setting these screens. It resembled an inverted steel funnel the size of the screens, the rim sharpened, the apex fitted with a vertical handle. It was not satisfactory.

These screens withstand heavy winter snow and are large enough to permit seedlings to grow unhampered for one season. The screens reduce maximum temperatures inside from 2^{o} to 5^{o} F. If used repeatedly in the same locations white-footed mice apparently learn to enter them systematically. The degree of effectiveness of these screens is indicated by the following comparisons of germination in screened and unscreened spots.

Date	Branch Station	Cover	Treatment	Number spots: Screened	Number spots: Unscreened	Germination percent: Screened	Germination percent: Unscreened
2/34	Blacks Mt.	Brush	Stripped	121	918	78	4
11/34	" "	"	"	400	400	64	7
11/35	" "	"	"	1000	2000	41	0.4
10/34	Feather River	Grass	Dug	924	258	46	8
10/34	Stanislaus	Timber	Burned	460	2140	91	83
10/34	"	Brush	Stripped	602	3440	46	5
11/35	Blacks Mt.	Timber	Logged	..	58906	..	10
11/36	" "	Brush	B.& Str.	1000	1000	77	24
5/37	" "	"	"	5400	..	92	..
10/37	" "	"	"	5400	..	81	..

Seedlings a few weeks old, which have dropped the seed coats and become woody, are rarely damaged by the smaller seed eating rodents. The seedlings are encumbered by the screens by the end of the first season of growth. Removal of the screens, on areas where there is ample cover, invites serious damage to the trees by cottontails, and possibly other rabbits and porcupines. In the 5/37 and 10/37 Blacks Mountain experiments the seedlings were sprayed, when the screens were removed, with a poison formula used by the Biological Survey. Under the particular circumstances, this treatment did not give adequate protection.

Source of Seed. The Genetics Division of the Station has a complex experiment under way which admits comparison of ponderosa pine seed of different sizes, seed from several types of trees, and from several altitudinal sources. A working plan has been prepared and first year results are being compiled and analyzed.

Methods of seed storage and treatments to increase germination are being studied by the same division. Results to date are available as file reports and published articles by N. T. Mirov.

ARTIFICIAL SEEDING OF TREE SPECIES IN THE INTERMOUNTAIN REGION:

PRESENT STATUS AND FUTURE POSSIBILITIES.

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Introduction

Artificial (direct) seeding of timber species made its debut in the Intermountain region almost three decades ago, and for several years proceeded on a rather grandiose scale. Following the first wave of enthusiasm, sporadic attempts continued until the early twenties. By 1925 Korstian and Baker (4) were ready to admit that seeding had proven unsuccessful and had no place in the regeneration program of the region. Viewed in retrospect the early trials at first thought might appear an adequate demonstration of the futility of the method. After all, they were cloaked in the convincing grandeur of size and seasonal "replications." But on second and more critical thought, they lose "stature" and cogency by the very promiscuity that characterized their execution. Have it as you will, the fact remains that there are still individuals, both old and young, whose faith early failures did not shatter, and to whom the possibility of artificial seeding as a potent tool of regeneration has never quite lost its appeal. Many still hope that seeding will succeed, but it is a hope born of faith rather than conviction based on adequate experimental evidence.

In recent years experimentation in this field has been renewed in many regions, without benefit of fanfare, with small but more carefully planned studies designed to tell something about the causes of failure and the factors of success. In this new work there also appears evidence of a refreshing departure from the old philosophy that colored the justifications for seeding thirty years ago. The major emphasis in the early days rested heavily on initial costs. For some reason seeding just had to be cheaper than planting, else it could never be justified. (In many instances seeding was also expected to succeed on areas too difficult to plant.) There appears no logical basis for assuming that seeding must proceed under these handicaps. It has every right to be tried on choice sites and to cost as much as planting (though not more). In comparisons of this sort the important and equitable points to consider are that the final costs of seeding when measured in terms of unit areas of successfully restocked land are not substantially higher than in planting and that the objectives of the regeneration program have been satisfactorily fulfilled in either case.

The foregoing remarks have been made to dispel arguments that early experience, particularly in the Intermountain region, makes revival of direct seeding entirely futile. Evidence gathered since 1935, though by no

means conclusive, indicates considerable promise for seeding of ponderosa pine in central Idaho. It should be clearly pointed out right at the start that results obtained in the Boise Basin should not be construed as indicative of response elsewhere in the region. Differences in species and numbers of rodents, differences in character and amount of spring to fall precipitation, and differences in soils are sufficiently great between various portions of the region to vitiate as yet any broad comparisons. The purpose of this report is primarily to show the present status of artificial seeding in the Intermountain Region and to briefly prognosticate what the future holds.

Review of Early Work

There are not many specific references to early work in this region, excepting accounts of Uinta and Minidoka seedings (1) (4). It might be interesting and worth while, however, to review work in other western states to obtain a general picture of the scope of the trials, cost estimates, and something concerning factors responsible for success or failure.

Cox (1) reported that in 1909 seeding plots were laid out on almost all of the western forests. Out of these, eleven were considered successful. Douglas-fir, on the whole, gave best results. Lodgepole pine, Sitka spruce, and western redcedar succeeded only in very rare instances. According to Wahlenberg (7), in 1910 over 15,000 acres were sown to various species. Barely 6 percent of the seedlings resulting from this promiscuous scattering of seed was reported as surviving.

Murdock (6) reported that on the Custer Peak experimental area 28 acres were sown broadcast and 12 acres sown with corn planter, both seedings being made in late May 1905. The season was exceptionally wet; survival very good with best stands in heaviest sod! Seedings in 1906 were poor; in 1907, good; in 1908, poor. In 1909, 650 acres were broadcast sown, resulting in a catch of 100 to 200 seedlings per acre. Rodents caused the heaviest losses. Cost of seeding varied with ground preparation, being $31.66 per acre for careful spots, $12.00 per acre for modified spots, $5.50 per acre for furrows, $1.50 to $3.80 per acre for corn planter, and $2.05 to $2.65 per acre for broadcast sowing at the rate of 4 pounds of seed per acre.

In the spring of 1911, Larsen and Smith (5) carried out a study also in the Black Hills. A ponderosa pine seeding on a bare south exposure of a 1910 burn produced seedlings in every seed spot. At the same time, a sowing on a north exposure of the same burn yielded fair results only in the case of the seed spots. This north exposure had a fairly dense sod cover as contrasted to the bare south aspect. Corn planter sowings failed completely, failure being blamed on sod, rodents, and drought.

In 1913 Willis (8) attempted to protect ponderosa pine seeds from rodents by (a) planting deep, (b) poisoning, (c) screening, and (d) spraying seeds with chemicals having obnoxious odors. Deep planting protected seeds from rodents, but prevented most of the seedlings from breaking

through to the surface. Wholesale poisoning proved ineffective. Sowing seed in screen wire was not worth the cost. (?) Covering seed spots with tar roofing gave good protection. Complete protection was provided only by wire cones, but the method was considered too costly in view of the fact that the cones had not eliminated drought mortality. Obnoxious chemicals were ineffective. White-footed mice were particularly destructive, devouring large quantities of field-sown seed.

Despite the fact that available literature on the subject of artificial (direct) seeding reads like a history of triumphless campaigning, among the many failures were some notable successes. The early studies indicate that (a) for comparatively heat resistant species like ponderosa pine a bare mineral soil with competition at a minimum constitutes a reasonably favorable site, and (b) that some means of protecting seed from rodents and birds is imperative. It is not expected that these conclusions will be materially altered by additional experimentation. Where competition from a well-established ground cover is severe and rodents numerous, success comes only during wet years and under a certain combination of conditions neither well defined nor fully understood. It is the job of today's research to define and evaluate these factors and conditions so clearly and so well that failures (if we must have any) will occur only when departures have been made from prescribed procedure.

Outline of Recent Exploratory Studies in the Intermountain Region

Since November 1935, the Intermountain Station has conducted a number of exploratory seeding trials on ponderosa pine in central Idaho. Specifically these studies include:

1. A "paired spot" test using 1/2 inch mesh galvanized hardware cloth cages versus no protection, and involving total of 540 spots sown in November 1935.

2. A test using 12-mesh window screen tubes versus no protection in "randomized block" arrangement involving 4 aspects, 3 separate locations, and 1680 spots seeded first in October 1936, and repeated in May 1937 and in October 1937.

3. A test using (a) small 1/3-inch mesh hardware cloth cones, (b) 1/2-inch mesh hardware cloth cages, (c) 12-mesh window screen tubes, no protection. Seeding made October 1937 on a fresh clean burn in a Latin Square involving 180 spots.

4. A test using (a) 1/3-inch mesh hardware cloth cones with no shade and with shade from shingle slabs; (b) 1/3-inch mesh hardware cloth cages with and without shingle slab shade, and (c) no protection. Seeding made in October 1937 in a 4 x 4 Latin Square on a 4-year-old brushed over burn, involving 320 spots.

5. A test using (a) 1/3-inch mesh hardware cloth cones with and without shade; (b) 1/3-inch mesh hardware cloth cages with and without shade; (c) 12-mesh window screen shade with and without shade. Seeding made October 1937 in a 6 x 6 Latin Square involving 720 spots.

Details and Preliminary Results of Exploratory Experiments

As indicated in the outline above, the first one of a series of informal exploratory seeding studies was initiated in November 1935. This consisted of series of paired spots in adjacent transects 5 feet apart, crossing several minor draws and ridges on the 1934 Elk Creek burn. Each spot consisted of a shallow hole dug with a hoe. Five seeds were placed in each hole and covered to a depth of 3/4- to 1 inch with dirt firmly tamped over the seed. Snow from the first autumn storm still lay in patches over the seeding area, though most of the ground was bare. The surface soil froze hard every night, thawing out sufficiently during the day to permit seeding. The late seeding and the deep soil cover were effective in eliminating autumn losses of seed. As a matter of fact, rodents did not appear to be abundant on the area, owing at least in part to the severe fire (20,000 acres) that had ravaged this locality a year before. On May 9 of the following spring, just as the seeds were beginning to germinate, hardware cloth cages (1/2-inch mesh) about $3\frac{1}{2}$ inches in diameter, about 8 inches high, were placed over half of the spots. Later it was found necessary to drive a stake by each screen and to wire the cage to the stake to prevent the screen from being knocked over by cattle and sheep. (This is a very necessary precaution in heavily grazed areas and represents one of several disadvantages of wire cages.)

Inspections during the germination period revealed the folly of planting seed too deep on burns. While this practice had apparently afforded good protection against rodent and bird depredations, a very substantial percentage of the seedlings failed to penetrate the soil layer which dried out rapidly and fairly early in the spring. There was a tendency toward cementation in the top layer of soil, doubtless accentuated by the comparatively large quantities of ash and carbon left on the surface from the recent fire. Examinations showed that seed germinated without difficulty, but could not break through, consequently dying below the surface.

Intensive observations and records were kept only on the spots having seedlings that succeeded in breaking through, so the data in the following tables are based on these rather than on the total number of spots sown.

Table 1. - Rate of decrease in percentages[1] of successful[2] spots and total numbers of living seedlings during the first growing season. (Ponderosa pine seeding; November 1935, Elk Creek Burn.)

	5-9-1936	6-3-36	7-10-36	9-5-36	10-31-36
	Screened series[3]				
	Percent	Percent	Percent	Percent	Percent
Spots	100	83.5	78.8	68.2	64.8
Seedlings	100	75.4	68.8	58.4	56.0
	Unprotected series[4]				
Spots	100	74.0	58.4	46.8	42.7
Seedlings	100	73.1	53.8	41.4	34.6

1/ Basis - total germination.
2/ A spot with one or more living seedlings was termed "successful."
3/ Total germination equalled 48.7 percent) based on total number of seed sown in successful spots.
4/ Total germination equalled 43.3 percent) based on total number of seed sown in successful spots.

It is evident that the screen cages are advantageous but the superiority is not so great as one might expect. The comparatively small difference is due in part to scarcity of rodents on this burn and to the heavy toll taken by heat and drought in both screened and unscreened spots. Of the total numbers of seedlings that died in screened spots, 81 percent were attributed to heat and drought, 12 percent to trampling by cattle and sheep, and the remaining 7 percent to damping-off. In the unprotected spots, only 57 percent were attributed to heat and drought, 14 percent to cattle trampling, and the remainder to rodents and birds. It is possible that the shading afforded by the screens is sufficient to encourage growth of damping-off organisms but the data from this study are too meager to be conclusive in this regard.

The advantage of screening is more apparent at the end of the third year than at the termination of the first growing season. This test does not tell what might have happened had the screens been removed in the autumn of 1936 instead of a year later. It is highly probable that protection for the first two growing seasons and possibly even through the second winter has some real advantages. In seeding as in planting, the mortality curve has a similar trend, plateau formation being evident after the second year.

Table 2. - Rate of yearly decrease in percentages of successful spots and total number of living seedlings. (Elk Creek Burn ponderosa pine seeding, November 1935.)

	October 1936	October 1937 1/	October 1938
	Screened series		
	Percent	Percent	Percent
Spots	64.8	56.6	56.6
Seedlings	56	45.3	43.8
	Unprotected series		
Spots	42.7	31.6	27.4
Seedlings	34.6	28.4	26.9

1/ Cages removed October 1937, i.e. the end of the second growing season.

Growth of seedlings. The question arises regarding the rapidity of growth of seedlings in sown spots. It is natural to assume that development in spots without site preparation should be poorer than that of native seedlings in view of the crowding and competition between clumps of seedlings in all spots, in addition to actual mechanical interferences by the hardware cloth in protected spots. To obtain an indication of growth in both unprotected and screened spots, all seedlings were measured at the end of the third growing season.

The mean difference was not significant. No direct comparison is available between growth performance of seedlings in artificially sown spots and of native stock. The seedlings in these spots did not get started until May 1936, more than a year after the fire, and since no site preparation was attempted, competition, particularly from brush, was already severe. Their growth and appearance so far are poor. Had seeding been made immediately after the fire much better growth might have been obtained. It is also probable that seedlings in crowded spots need to be thinned in the second or third year in order to insure proper growth and development.

Test No. 2 was initiated in October 1936 with the idea of finding out whether the small japanned window screen tubes can be used effectively under central Idaho conditions. Seeding plots were laid out in three separate locations: (1) the station area near Idaho City; (2) the Elk Creek burn; and (3) the open grass-brush areas at the head of Bannock Creek. At each location plots were placed on (1) a ridge top, (2) a draw bottom, (3) a north slope, and (4) a south slope, with provisions for 3 seasonal replications. Seeds were sown in unprepared spots in rows 6 feet apart, with the seed in half the spots protected by window screen tubes. Only 3

seeds were placed in each spot whether screened or unprotected. A total of 1680 spots were under observation from each sowing, and the seedings were reported in May 1937 and again in October 1937.

The first examination of the October 1936 seeding was made in June 1937. Although a surprisingly large number of seed had germinated in the unprotected spots, the protective value of the screens was already clearly evident. The discussion below will serve to illustrate some of the differences.

Location differences were significant, aspect and aspect-location differences highly significant.

The biggest differences occurred on the draw aspect, the smallest on the north. The small difference between north aspect screened and unscreened spots is not surprising; it is in concordance with measurements and observations in natural regeneration factor studies (2) and may reflect real relationships between feeding habits of rodents and vegetational development as affected by rate of snow recession on different aspects.

To determine whether total[1/] germination was significantly different by aspects or locations an analysis was made of the data from the June 1937 counts.

Neither aspect nor location introduced significant differences in total germination. Interaction of these two is highly significant, however, for reasons not readily apparent. Differences within north aspects are again of low magnitude.

From the foregoing discussion it might be inferred that the screen tubes in general were quite effective, and a promising technique in artificial seeding in central Idaho. This is an erroneous impression. To be sure, the tubes gave adequate protection to the seed and the seedlings insofar as rodent and bird depredations were concerned, but they could not and did not eliminate normal drought and heat losses. Quite the contrary, the black (japanned) screen tube appeared to induce high heat mortality. They may also induce excessive damping-off. At the end of the first growing season only a few seedlings survived. Heat and drought had been apparently the chief causes of mortality, since actual counts showed that the numbers of seedlings present in the tubes in October were practically the same as in June.

1/ Total germination percentage refers to ratio of total number of seedlings appearing to total number of seed planted in all spots (both successful and unsuccessful).

The May 1937 and October 1937 seedings employing the same technique as above showed equally poor results. The screen tube is definitely not suited to central Idaho conditions. On the one hand it appears to induce heat losses; on the other it is not sufficiently large to accommodate an adequate number of either seeds or seedlings to offset normal germination and heat and drought losses, nor does it appear to rust and fall to pieces under the dry climatic conditions of central Idaho as early as would be desirable (though this feature could possibly be remedied by acid treatment before sowing time). In addition it is easily crushed by cattle and sheep and could not be employed where heavy grazing use is being made of the area.

One other point from this study is worth mentioning, namely, the response from spring sowings. Only once has this been attempted, and it resulted in no germination in the first growing season. The interesting feature was that a very appreciable number of the seed germinated a year later, attesting to the "hold-over" viability of ponderosa seed even when subjected to the high surface soil temperatures that normally prevail throughout the summer.

The screens seem to have exercised a slight protective effect, but the results are quite variable, serving primarily as a measure of the magnitude of delayed germination and as an interesting substantiation of what had been previously observed and noted in natural regeneration studies.

Other tests. The purpose of tests Nos. 3, 4, and 5 was to make a direct comparison of the protective value of hardware cloth cones and cylinders, and window screen tubes. In addition an attempt was made to find out effects of artificial shading by using cedar shingle slabs.

Cones were eminently successful. Cylinders and tubes were essentially failures. Shading showed no beneficial effects; if anything, it was harmful, but the net influence of the artificial shading was obscured by the presence of at least a small amount of natural shading from brush and weeds on all spots. It is possible that artificial shading (or any shade for that matter) in the early spring is actually harmful, but if put into effect after germination is complete would aid in minimizing heat kill. This point needs further investigation if it proves to be an important item.

The cylinders failed largely because the tops were not closed over entirely, about an inch hole being left after the top one-fourth of the cylinder sides were bashed inward. Apparently, this opening was sufficiently large to permit mice to enter. Some loss was also evident from frost heaving of both cones and cylinders, and subsequent failure of these to resettle solidly against the surface soil. This failure was accentuated by the practice of using two No. 9 wire pins to hold the cone or cylinder more firmly in place. Actually what happened was a tendency for the cones to remain suspended on the pins after being heaved clear of the surface. It is thought that loss from this source can be largely eliminated by not using these pins.

The perfect performance of cones on the West Bannock burn is due not only to the good protection afforded by cones but also to the absence of practically all competition. No site preparation was attempted on any of the seedings, but the recent fire on the West Bannock area was unquestionably a big help. On the other areas, brush and weed competition was relatively severe.

Lessons Learned from Exploratory Tests

These exploratory tests have aided very materially in focusing attention on the important problems that must be solved if artificial seeding is to succeed. Many of the results from such exiguous studies as these are necessarily more indicative than conclusive, but it is expected that additional experimentation will only confirm and not materially alter the present indications.

For ponderosa pine on the granitic soils of central Idaho the following points are fairly well established:

1. That seed and young seedlings must be protected from rodents. Broadcasting or sowing in spots without protection is an appalling waste of seed except possibly when such seeding is done on large burns, well inward from the borders, and immediately (i.e. before brush growth begins) after the fire.

2. That competition from brush, grass, and weeds must be reduced by some means or another. Sowing immediately after a fire offers a partial solution but on old brushed-over burns some means must be found to reduce competition. Skid trails, burned brush pile sites, etc., on cut-over areas offer good seeding chances. Release cuttings or weedings may be necessary during the early years.

3. That fall sowing is better than spring sowing provided complete protection is effected. Ordinarily untreated seed cannot be sown early enough in the spring in central Idaho to obtain satisfactory germination. Unless seed can be treated to induce very rapid germination, fall sown seed will enjoy a big advantage over spring sown seed.

4. That small window screen tubes are not satisfactory. Heat kill under central Idaho conditions is tremendous. Enlarging screens introduces problem of excluding rodents.

5. That hardware cloth cylinders or cages are not recommended. Closing ends of cages is a big job; leaving holes in top allows rodents to enter. Cylinders have the additional disadvantages that they are readily knocked over, and do not nest, hence are too bulky for packing to the field and back.

6. That 1/3-inch (3 x 3) mesh hardware cloth cones furnish sufficient protection against ordinary rodents and birds of central Idaho. One-half-inch mesh cloth is coarse enough to allow small mice to enter; 4 x 4 mesh would furnish more shade (to reduce heat kill) but costs more. These two cloths need direct testing to determine whether material advantages accrue from the finer-mesh, higher priced cloth; the extra shade may be actually harmful. Cones have the advantage of nesting--a real asset in packing.

7. That young seedlings must be protected until stems are definitely suberized. At this rate, cones should be left on at least until about the middle of August in the first growing season. Retaining the cone protection through the first winter or even through the second growing season may be worth while.

8. That grazing must be excluded during the first few years. It is imperative to exclude sheep; and it is necessary either to exclude entirely or to restrict the numbers of cattle on seeded areas. Injury from grazing livestock takes many forms: knocking over cone protection; trampling cones, trampling and browsing seedlings. The idea that grazing is helpful because it reduces competition from lesser vegetation is without real foundation. Grazing to be effective would have to be so severe as to be ruinous from other standpoints. In other words, it would have to be of an intensity obtained only on sheep driveways, which might indeed be utilized to advantage.

9. That only about 50 percent of clean and sound ponderosa pine seed can be expected to germinate under the natural conditions encountered in seeding. Adequate allowance must be made for germination failures which are fairly constant, and for drought and heat losses which are as yet largely unpredictable.

A Brief Description of Present Studies

The exploratory tests cited above have largely been abandoned, but two new studies have been initiated in the Boise Basin. Both of the new studies are fairly comprehensive. The first of these involves a test of seeding only; the second involves both seeding and planting.

Test No. 1. This test is a fall sowing of ponderosa pine in 9 separate drainages in the Boise Basin. Variables in this test are cone size, degree of scalping, and time of removal of cones. The two cone sizes are: (1) the small type with about a 6-inch basal diameter and height of about $5\frac{1}{2}$ inches. This size is considered the smallest suitable for ponderosa pine. Even this size tends to cause some crowding but the effects do not appear particularly harmful as yet; (2) the large type with about a $10\frac{1}{2}$-inch basal diameter and height of about $10\frac{1}{2}$ inches. This size is considered about the largest suitable for ponderosa pine or for any other species

for that matter because of weight and cost. It has an ample basal area, affording some spreading of seed at sowing time and also enough height to allow leaving it on for at least two growing seasons without crowding the center seedlings in the case of ponderosa pine. Somewhere between these two limits, there is perhaps a cone size optimum from the standpoint of weight, cost, roominess, and general utility.

Degree of scalping. Three degrees of scalping comprise:

(a) No treatment.
(b) Scalps 12 inches x 12 inches by 4 inches deep.
(c) Scalps 30 inches x 30 inches by 6 inches deep.

This is intended to show whether any reasonable amount of scalping is helpful. It is possible that local scalping is futile, and that aside from burning, nothing less than fairly drastic contour furrowing is effective in reducing competition sufficiently to affect seedling survival and growth.

Time of removal of cones. Six different dates of removal are scheduled in this test. They are:

1. Immediately.
2. In the spring after snow melts.
3. In June after germination is complete.
4. In August after stems are definitely "suberized."
5. In October of first growing season.
6. In October of second growing season.

Information from the different removal dates is expected to give a fairly thorough insight into rodent and bird activity and may be helpful in devising cheaper methods of protection.

Test No. 2. This test involves direct comparisons of the following:

1. Ponderosa pine fall seeding with large cones.
2. Ponderosa pine spring seeding with large cones.
3. Ponderosa pine fall seeding with AAA netting cover.
4. Ponderosa pine spring seeding with AAA netting cover.
5. Ponderosa pine fall planting - Bannock Creek Nursery 3-0 stock.
6. Ponderosa pine spring planting - Bannock Creek Nursery 3-0 stock.

The test further involves the same 3 degrees of scalping as used in test No. 1. The AAA netting is being tried out because of the relatively high order of protection exhibited by it in nursery seed beds. The spring seeding in this test will employ pretreated seed to hasten germination. Untreated seed is already known to fail in spring sowing (except possibly in very wet years). Seed and seedlings are sown in blocks in 3 major drainages. Treatments are randomized by rows which are 8 feet apart and spots 5 feet apart in rows, 15 spots per row. Treatments are replicated twice in each block, at random of course, to serve as a measure of error.

It is intended to repeat both tests 1 and 2 over a period of two or three years with such minor modifications as additional experience or instructions may indicate as desirable.

The Outlook

It is unfortunate that the severe setbacks of the early years resulted in complete stagnation of thought and effort in the field of artificial reseeding; it resembles still pretty much of a trackless sea with progress in charting safe courses delayed by the pioneering failures. Today there is so much to do and so little with which to begin. Enough has been found in recent tests to encourage further work, but it is not at all certain that the present lines of investigation are heading directly to the most effective technique. One thing appears certain already, namely that for ponderosa pine in Central Idaho the successful way does not lie in the direction of promiscuous scattering of seed but rather in fewer seed more adequately hidden from rodents, and more fully protected from heat and drought during critical periods. One needs only to consider the arithmetic of Nature to realize what tremendous odds seed and seedlings have to overcome. For example, in the Pine Creek area of the Boise Basin, combined measurements and estimates by seed traps (3) indicated a mean seedfall of 307,000 seed per acre in selectively cut stands of ponderosa pine. This is equivalent to more than 36 pounds per acre! This amount of seed resulted in a mean germination of 5,052 seedlings per acre, of which only 558 seedlings survived at the end of the first year! Five hundred and fifty-eight 1-year-old seedlings per acre cannot be considered a satisfactory catch in central Idaho. Nature attempts to offset the effects of heat, drought, and predators by sheer force of numbers, but man cannot hope to, should not want to, emulate such an egregious practice, such a gross technique. He must resort to craft and cunning, to skill and guile.

Numerous possibilities remain unplumbed. The tests described in this report represent rather crude, cumbersome, and costly methods. It is probable that seeding will always involve some "strong-arm" practices, particularly in the site preparation phases. But there are still the relatively unprobed avenues of fertilizing, of repellents, of pretreated or pregerminated seed, of local poisons, yes, even the much-maligned <u>agar pellets</u>. These alone or in various combinations with mechanical devices may turn the trick. And there is always the very real possibility that a method that works beautifully under the dry summers and coarse, acid, granitic soils of central Idaho may fail completely in the heavy alkaline soils and the comparatively abundant summer rainfall of Utah. At this late stage no seemingly harebrained idea should be entirely condemned, no criticism contemptuously ignored. Nor should it be considered that in the Intermountain Region seeding has been given the same opportunity as planting. Neither are as yet satisfactory; both should receive a fair and adequate trial.

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A REVIEW OF DIRECT SEEDING

IN THE NORTHERN ROCKY MOUNTAIN REGION

by

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Administrative Seeding

The history of forestation by the U. S. Forest Service in the Northern Rocky Mountain region starts in the year 1908 when attempts were made to establish trees on a large scale over extensive areas in eastern Montana in the ponderosa pine type. At this time direct seeding was the only method used. Seeding was accomplished in a number of ways; i.e., sowing seed in plowed furrows, broadcast sowing both on snow and exposed natural ground surface, sowing with a corn planter, and also by hand in spots. The results of this work were far from successful. By 1910 the failure of a number of the seeded areas became apparent and the utility of seeding was questioned. However, the 1910 fire left two million acres of land in need of forestation. This burned-over area provided what was then believed to be a good place to sow the thousands of pounds of seed which were on hand at that time. Hence, seeding continued to be used until 1913 when the number of failures became so appalling that seeding was discontinued except for experimental purposes.

A summary of the results of early sowing projects in table 1 strikingly shows the general failure of direct seeding as a means of forestation.

The table shows that establishment of 250 or more trees per acre occurred on only 5 percent of the total seeded area. Outstanding success in a few instances was attributed to favorable weather conditions during the growing season after sowing. Present knowledge of the habits of chipmunks and field mice indicates that these and other rodents must have been very scarce on the few successfully seeded areas. Records fail to show what caused the general failure of seeding. It is believed now that in general these failures may be attributed to sowing on unfavorable sites, lack of protection of seed from rodents, and unsuitable methods of sowing.

Past Experimental Work on Seeding

Between 1916 and 1921 a series of intensive experiments were made to compare the adaptability of the various species to seeding methods. These experiments are described and summarized by Wahlenberg (5).

The standard method of sowing consisted of placing 20-25 seeds on a spot 6-8 inches square prepared by scalping with a planting mattock. Seeds

were tamped into the soil, covered to the desired depth by hand, and left untamped. The depths used were three-eighth inch for western white pine and ponderosa pine, one-fourth inch for Douglas-fir and Engelmann spruce, and one-eighth inch for western redcedar.

Table 1. -- Survival on seeded areas[1/]

Species	No. of sowings	Total acreage	Area by survival classes: 0-99 trees per acre: Percent of total acreage	100-249 trees per acre: Percent of total acreage	250-499 trees per acre: Percent of total acreage	500 or more trees per acre: Percent of total acreage	All classes: Total percentage
Pinus ponderosa	240	7,661	82	11	6	1	100
P. monticola	44	7,800	80	17	0	3	100
Picea engelmannii	13	211	100	0	0	0	100
Other conifers	136	1,576	94	6	0	0	100
Hardwoods	18	120	96	0	4	0	100
All species	451	17,368	82	13	3	2	100

1/ Data taken from Annual Planting Report, Region One, 1937.

Rodent depredations in spots containing seed of the larger seeded species, western white pine and ponderosa pine, left practically no seed to germinate. Masking the spots with litter for protection from rodents was ineffective. In 1921 some screened spots were sown but drought killed all germinated seedlings before August in the following growing season.

Spots were examined at 10-day intervals and the number of dead seedlings was recorded by causes. The causes of mortality in the decreasing order of their destructiveness were drought, cutworms, fungi (damping-off), and frost heaving.

After five years of experimental sowing, Douglas-fir had the best record with one or more seedlings in 20 percent of the spots. No other species had seedlings in more than 15 percent of the spots. Wahlenberg

admitted after making these studies that direct seeding may have a place in the forestation program of this region, but that it had not yet been discovered. Seeding experiments were then discontinued.

Current Seeding Studies

With the advent of the CCC and other emergency programs a much larger supply of labor was provided for forest work than ever existed before, and interest in direct seeding revived. The few successfully seeded areas in this and other regions indicate that forestation can be accomplished by seeding provided that we know when, where, and how to sow seed. Believing that the previous work did not provide adequate information on these problems, Hornby and Weidman revived direct seeding studies at this Station in 1936. Weidman (6) wrote a preliminary working plan explaining the need, advantages, disadvantages, and proposed methods of seeding.

In the fall of 1936, a plot was established to test the efficiency of methods of sowing on burned-over land. In this plot, a 4 x 4 latin square, four methods of covering western white pine seed spots were tested:

1. Mineral soil tamped
2. Mineral soil untamped
3. Ashes tamped
4. Ashes untamped

Within each treatment a test was also made of the effectiveness of conical screens made of two-mesh hardware cloth for protection against rodents. Seedling counts at the end of the following growing season showed that 29 percent of the screened spots had one or more live seedlings while only 8 percent of the unscreened spots contained seedlings. No apparent differences were observed between coverage treatments.

A second installation was made on a burned-over area to determine the relative amount of rodent depredation on seed spots at distances of 400, 800, and 1,200 feet from green timber. Species used were western white pine, ponderosa pine and Engelmann spruce. No consistent difference in germination at the various distances was observed within species.

A serious difficulty with these installations was poor viability of the seed used in the experiments. Germination percentages were as follows: Western white pine, 17; ponderosa pine, 4; and Engelmann spruce, 50. This low viability greatly weakens the significance of the results obtained.

In the fall of 1937, Schopmeyer (1, 2) took over the seeding work and installed four latin square plots. Two of these plots were on north slopes in the Coeur d'Alene Forest and two were on open flats in the Kaniksu Forest. All areas had been clear-cut and broadcast burned within a year previous to the time of sowing. Three species, western white pine, ponderosa pine, and Engelmann spruce, were sown. On these three species tests were made of the effect of cultivation by comparing germination and survival on cultivated spots and on uncultivated spots. In addition,

comparisons were made between spots protected with conical screens and unprotected spots to obtain information on rodent damage. In the spring of 1938 (3) a similar spot was installed beside each of the fall sown plots to determine the effect of season of planting on the various treatments. The same treatments were used in the spring sown plots as were used in the fall sown plots and in addition a small test was made of the effectiveness of a poison coating on the seed as a rodent repellent. The coating was recommended by the U. S. Biological Survey, Control Methods Laboratory, and consists of 48 percent yellow dextrine, 31 percent plaster of paris, 15 percent yellow corn meal, and 6 percent strychnine alkaloid. All the white pine seed used in the spring was stratified in moist sand for about 7 weeks before sowing.

All plots were examined four times during the 1938 growing season, and records kept of germination and mortality by causes. Briefly, data from these examinations definitely show three things: (1) Under the conditions of this experiment fall sowing resulted in much better stocking than spring sowing. (2) Stocking in screened spots was much greater than in unscreened spots (about 95 percent as compared to 40 percent). (3) Seed of Engelmann spruce, probably because of its small size, was not as susceptible to rodent depredations as white pine and ponderosa pine. Seedlings were much more vigorous and numerous in the screened spots than in the unscreened spots. Perhaps the shading effect of the screens is a factor contributing to the vigor. Undoubtedly the protection against rodents afforded by the screens is the factor which accounts for the greater numbers because rodent depredations were observed on practically all unscreened spots within 2 days after sowing.

A small test of several commercial rodent repellents was installed in the spring of 1938 along with the strychnine mixture recommended by the Biological Survey. Seed of ponderosa pine was treated with "No Crow", "Bye Bye Blackbird", "Crotox", and the strychnine mixture. Blocks of 48 spots each were installed along with a check block of untreated seed. Rodent depredation was least severe on the check block indicating that the so-called repellents were ineffective.

It is believed that the small tests of poison-coated seed were not adequate. In the first place, the effectiveness of the coating apparently does not depend upon a repelling property but on its toxic property. On a small area, poison-coated seed will kill off a few rodents but others will move in and clean out all seed. In the second place, germination after spring sowing was poor even under screens when compared to germination after fall sowing.

To get a more reliable test, a 50-acre broadcast burned area was sown with poison-coated seed during the fall of 1938. On this area, additional rodent protection was provided by spreading poisoned bait on the surface of the ground. The bait consisted of hulled sunflower seed treated with thallium sulfate.

The sowing procedure used on this area may be of interest. A 12-man crew of CCC enrollees was used for the sowing job. Each man was provided with a hazel hoe for preparing the spots and a seed container carried on his belt. The container was a tin can, size $2\frac{1}{2}$, with the top removed. Such cans may be obtained, with tops already removed, at any Forest Service cook house. Each can was provided with a metal belt loop and a wooden lid mounted on a spring hinge. Although the poison coating about doubled the volume of the seed, this container will hold more white pine seed than a man can sow in half a day. Spots were prepared by scraping off the ash and duff from area about 1 foot square. Soil was cultivated to a depth of approximately 6 inches. Roots up to $1\frac{1}{2}$ inches in diameter were readily removed when encountered. Spots were leveled by tamping with the back of the hoe. About 20 seeds were measured out with a one-fourth teaspoon measure and placed on the spot. Instructions were to cover the seed with one-fourth inch of mineral soil, but in checking spots for proper depth of sowing, many were found where the depth was greater than one-fourth inch.

Experimental installations of western redcedar seed were made on a number of different sites in the fall of 1938. The types of sites included are:

1. A recently burned north slope.
2. A recently burned flat.
3. A 3-year-old white pine plantation on an old broadcast burned north slope.
4. A sapling stand of western white pine on a northwest slope.
5. A north slope covered with ceanothus and willow brush.

It is expected that redcedar seed, because of its small size, will not be susceptible to rodent depredation. However, this species makes very little root penetration during its first growing season and for that reason mortality caused by drought may be high on exposed sites. Its tolerant nature, however, may enable it to survive under the shade of other species in direct competition with them for soil moisture and nutrients. These installations are expected to give some indication of the type of sites suitable for sowing with this species.

In addition to the work at this Station, Tinsley (4) at the University of Idaho reported some success with screened spots of western white pine seed.

Future of Direct Seeding

The results on the recent seeding projects are very encouraging. However, past failures make more research necessary before seeding can be recommended as a practical forestation method in this region. First, of course, the rodent problem must be solved. Second, a better knowledge of sites suitable for establishment of seedlings of each species by direct seeding methods must be obtained.

One very effective method of rodent control is physical exclusion of rodents from seed spots with screens. However, the screens available at present are too expensive for large scale use. Development of an economical means of physical protection, preferably one that would also ameliorate drought and insolation injury, would be a satisfactory solution to the rodent problem. The development of such protection, since it is probably applicable to all regions, might be made an interstation project with the cooperation of the Forest Products Laboratory.

Rodents may also be controlled by the use of chemical repellents or poisons. No effective repellent has yet been devised to our knowledge. The Biological Survey recommends poison which, as mentioned previously, is now being tried at this Station. Repellents or poisons, if successful, would probably be cheaper than any type of physical protection such as screens. On sites where drought or insolation is not critical, such substances may be very useful.

The second problem, which concerns the need for better knowledge of potential seeding sites, is a big one. Much of our present knowledge of the factors controlling establishment of natural reproduction can be applied to direct seeding, but further tests under varied field conditions are necessary.

The success of direct seeding then depends on proper rodent control, selection of suitable sites, and the development of a practical and economical sowing technique. If these phases can be successfully worked out, direct seeding should be a valuable supplement to planting. Successful planting in this region depends largely on the abundance of available soil moisture during and immediately following the time of planting. Early spring is the best time to plant. However, the season is short, and at that time it is usually difficult to transport men through the mountains to the planting sites. Fall planting also can be done during only a very limited period of time and has been less successful than spring planting. Direct seeding, however, can best be done in the fall when its success is not contingent on soil moisture. Hence, it can be done over a much longer period than planting. Fall sowing of western white pine is practically mandatory because of the strong tendency of spring sown seed not to germinate until the following year. Development of successful direct seeding methods would lengthen the effective annual work period of the forestation program.

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DIRECT SEEDING IN THE SOUTHWEST

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Southwestern Forest & Range Experiment Station

Survey of Past Work

Direct seeding experiments in Region 3 began in 1909, employing both broadcasting and seed spot methods. The first results were failures mainly because of rodent activity. Germination was, in some instances, fairly good but the young seedlings were either bitten off by rodents, heaved out of the ground, or succumbed to drought. Rodent "repellents" such as red lead, blue vitriol, and creosote were ineffective. Poisoning failed to reduce the rodent population sufficiently. Protective screens promised to solve the rodent problem, though at prohibitive cost. Also, the mortality in screened seed spots was higher than in planting. In the light of present knowledge, failures attributed to drought could have been reduced by removal of competing vegetation. While direct seeding generally gave poor results, planting was much more successful and consequently this method soon replaced direct seeding. About 1918, all artificial reforestation was virtually dropped from the research program because of the overshadowing importance of other problems.

An experiment in "field nurseries" gave a clue to seed spot failures, and established the principles which determine success. Well-prepared seedbeds 4 x 6 feet in size and screened against rodents invariably produced good stands of seedlings without watering. The beds were weeded and, in addition, a marginal strip was kept clear of vegetation. Many such beds were established between 1913 and 1920. Ponderosa pine, Douglas-fir, and Engelmann spruce all succeeded. It gradually became evident that elimination of competing vegetation and covering the seed with soil were essential but that deep cultivation was not essential. As a study of natural reproduction, in 1929, a series of ponderosa pine beds was sown with and without removal of grass and with and without rodent exclusion. Plots exposed to rodents were almost a failure; inside a rodent exclosure by far the best results were obtained where the grass was removed by cutting below the root collar, and the plots weeded for 2 or 3 years. Similar sowings on denuded plots were repeated in 5 different years, with only one failure. These tests pointed clearly to seed supply, exclusion of rodents, a good seedbed, and removal of competing vegetation as the primary factors in both artificial seeding and natural reproduction.

With the introduction of the statistical method, various details of technique have been tested in seed spot sowing, with the result that definite advances have been made since 1934. The more important tests are here briefly outlined.

Experiments in Progress

1. Systematic Poisoning, Protection with Screens, and Seeding without Poisoning or Screens.

   Purpose. Determine effectiveness of systematic poisoning of a planting site a few months before planting, and again at the time seed is sown. Determine whether a screen would deflect rodents and withstand snowfall in winter. The above treatments to be checked against no protection.

   Results. Systematic poisoning and no protection resulted in almost complete failure. Screens successfully deflected rodents, and have withstood heavy winter snows. Spot survival for screens was almost 100 percent for the first season. This dropped to 70 percent the following year and then to 60 percent, where it has remained for 2 years.

   The above conclusions do not imply that there is no room for further studies in systematic poisonings.

2. Mechanical Treatment of Seed Spots.

   Purpose. Determine what can be done at the time of seeding a spot that will improve germination and survival.

   The following treatments which included the protection by a screen were tested over a period of 3 years.

   A. Ground scalped of vegetation; seed covered with 1/4 inch of soil.

   B. Same as above but spots weeded during growing season.

   C. Same as A, but spots covered with duff or pine needles.

   D. Same as A, but soil spaded before planting.

   E. Seed merely dropped in ground and covered with screen.

   Results. Greatest improvement came from covering seed with a light layer of soil. Treatments A to D were approximately 80 to 90 percent better than E. Weeding did not improve results as much as was expected due perhaps to the small area covered and a failure to weed spots a sufficient number of times. Addition of duff was beneficial in dry years, but in wet year there was no improvement. Spading showed no change.

3. Length of Seed Spot Planting Season.

<u>Purpose</u>. Determine over what period seed spot planting can be carried on successfully. Planting September 15, November 30, April 15, and June 30 was tested.

<u>Results</u>. No significant difference was found in the above planting dates. Planting season was then concluded to extend over the period of September 15 to June 30 of the following, exclusive, of course, over that period when snow and frost make planting impossible. Experience has shown, however, that germination can take place in May, as it did in 1919. Rainfall records indicate also that in occasional years germination in May or June may be followed by disastrous drought. These conditions are rare, however.

4. Effect of Screens.

<u>Purpose</u>. Determine whether a protective screen made from 1/4 inch and 1/2 inch mesh hardware cloth improved the results over no screen, and, if so, which mesh was preferable.

<u>Results</u>. Screens do improve germination and possibly early survival, but appear to interact with season. Years when precipitation is abundant and well distributed, the improvement is very small, if any. No difference was detected in the results secured from the 1/4 and 1/2 inch screens.

5. Cellophane Protectors.

<u>Purpose</u>. Determine the value of rodent deflectors made from cellophane (clear and translucent) and also the value of serval, duff, and peat moss mixed into soil.

<u>Results</u>. Cellophane deflectors caused temperature to rise as much as 25 degrees F. above outside temperature, which had an injurious effect on seedlings. Translucent deflectors were twice as good as the transparent ones. They are not recommended because of generally poor results and excessive cost, with no chance of re-use.

No undecomposed organic matter such as duff, serval, or peat moss should be mixed with the soil as it has harmful effect on survival. A top dressing of such material is advantageous, but it should not be <u>too</u> heavy.

6. Rodopel.

<u>Purpose</u>. Test of the efficiency of a commercial repellent called Rodopel.

<u>Results.</u> The repellent did not deflect rodents; if anything, it attracted them.

7. Elimination of Competition.

Purpose. Seedlings surviving on seed spots on which all vegetation has been scalped still have difficulty overcoming competition from weeds and grass the first as well as the following years. This experiment aimed to discover how much of the weed seed bearing topsoil could be removed and yet not seriously hinder the germination and development of seed and seedlings. The following comparisons were made: Vegetation scalped from ground surface, 2 inches of topsoil removed, 4 inches of topsoil removed, and 4 inches of topsoil removed with soil from below the 12 inches used to replace that excavated. The same was done to the two preceding treatments, only in this case soil was taken from an adjacent area at the 2-inch and 4-inch level.

Results. Soil removed to a depth of 2 inches gave the best results. Seedlings on these spots were 3 to 4 times larger than those growing on the scalped spots, or where herbaceous vegetation was undisturbed. Competition was practically nil on the 2-inch, 4-inch, and 12-inch areas. Present indications are such that no serious competition with other vegetation need be expected within the next 3 or 4 years.

Removal of the top layer of humus-bearing soil decreases the chances of germination in dry years. A light top dressing of duff will improve germination on soils from which humus has been removed, but the results are not nearly so effective as introducing soil rich in decomposed organic matter.

8. Size of Seed.

Purpose. Determine if the heavy mortality of seedlings occurring the first 2 years after planting can be reduced by sowing only large seed.

Results. Seeds larger than average produced twice as many seedlings as seed below average in size. Seedlings from large seed were also much sturdier than those from small seed. Even though the number of seed planted to a spot was increased in order to offset the lower germination of small seed, there was still a marked advantage in using over average size seed.

9. Test of Commercial Fertilizer.

Purpose. Compare the development of seedlings on soil taken from the 12-inch level treated with ammonium phosphate, ammonium sulphate, and Vigoro, respectively, with those grown on soil taken from underneath groups of old ponderosa pine and also on soil which formerly supported a heavy growth of bunchgrass.

Results. At the end of the first season, seedlings had developed only on spots which previously supported grass or on soil taken from below crowns of old ponderosa pine trees. The reason for this was the presence of humus which kept the soil sufficiently wet to bring about germination. Precipitation during this season was too poorly distributed to permit germination on mineral soil free from decomposed organic matter.

Cloudcroft Experimental Forest

by

Herman R. Krauch

Survey of Past Work

Direct seeding of Douglas-fir was begun in 1932 in connection with a study that sought to determine the factors influencing natural reproduction. Seed was sown broadcast, in meter square quadrats, on three adjacent but differently protected areas; namely, (1) closed to both rodents and livestock; (2) closed to livestock but open to rodents; and (3) left open to both rodents and livestock. In each area, different kinds of seedbed and different degrees of shade were compared. Sowings were made both in the summer and in the fall, in four successive years - 1932 to 1935. The consistently poor results obtained on the areas open to rodents clearly indicated the futility of direct seeding unless rodents (chiefly mice) were effectively controlled. The need of also controlling birds became evident when it was found that Juncos were getting seed sown inside of the rodent enclosures. Under rodent protection, the best results were obtained when a good seedbed was prepared and when the plot was partially shaded.

In 1935 experiments were begun in direct seeding of Douglas-fir in prepared spots. Subsequently the experiments were extended to include ponderosa and white pine. To protect the seed against both rodents and birds, the spots were covered with hardware cloth screens. As a check, half of the spots of each sowing were left unprotected. As expected, practically all of the unprotected spots failed, mainly because rodents got the seed; whereas protected spots generally were successful.

Several methods of controlling rodents have been employed. A commercial preparation sold under the trade name of Rodopel was tested both at Cloudcroft and at Fort Valley and in both places it proved worthless. The Biological Survey has done some experimental work in poisoning. Thus far, thallium has given the greatest promise of success. Until poisoning is demonstrated to be as reliable as protective screens, the latter method will be employed. Tests indicate that the screens can be removed after the first season. Open cellophane cylinders in place of wire screens have proven ineffective.

The important facts thus far developed at Cloudcroft are:

1. An abundant supply of seed is indispensable.

2. The seed must in some way be protected against rodents. This applies also to tender seedlings, but they are not disturbed much after the first season.

3. All species succeed better if a seedbed is prepared by removing herbaceous vegetation and by light cultivation. Deep cultivation is not necessary. The seeds should be covered with soil.

4. Partial shade favors germination and early development of Douglas-fir. It also favors germination of ponderosa pine, but can readily become too dense for later development of this species.

5. It has been demonstrated that by observing the above precautions, reforestation by direct seeding can be accomplished. The problem is how to control rodents at a reasonable cost. Experiments now in progress aim primarily at this problem.

Experiments in Progress

A. Seed Spotting.

1. Seed Spotting of Douglas-fir, Ponderosa Pine, and White Pine on Different Sites.

   Purpose. To determine possibility of reforesting cut-over lands by direct seeding in spots and to determine adaptability of species with reference to site and cover; also, to furnish data on factors influencing natural reproduction.

   Procedure. Spots prepared in long rows with 6-foot spacing between spots. Every other spot covered with a hardware cloth screen. Sowings made on various sites, particularly with reference to differences in temporary cover; ranging from denuded and open burns to burns now stocked with oak, aspen, and locust. Also includes partially cut mature stands of Douglas-fir-white fir on north slopes, and mixed ponderosa pine, white pine, and Douglas-fir on south slopes. First sowings made in 1935 and repeated annually to date.

2. Summer versus Fall Sowing.

   Purpose. To determine if sowing seed in the summer has any advantage over fall sowing, especially with reference to germination and survival. As fall sowing simulates natural seeding, the results shed light on factors influencing natural reproduction.

Procedure. Same as for (1). This experiment is, in fact, an integral part of (1).

3. Removal of Protective Screens from Douglas-fir Seed Spots at Different Intervals.

Purpose. To determine how long spots must be protected to insure safety of seedlings from rodent destruction.

Procedure. Experiment begun in 1937. Plots laid out on different sites, according to Latin square design, with 100 spots -- spaced 6 feet apart -- to each plot. Seed sowed July 6, 1937. Equal numbers of seeds sowed in each spot. All spots protected with hardware cloth screens. After germination was complete, screens were removed from 20 spots in each plot at 5 different intervals; namely, August 17, September 11, October 2, and November 13, of 1937, and July 6, 1938.

The experiment was repeated in 1938, using both cans and screens instead of screens only to protect spots. Inasmuch as the experiment of 1937 showed that up to the time the stems of seedlings became lignified rodents cut most of the seedlings, removal of screens before late fall did not seem justified. Therefore, first removal, in 1938, made on October 25. Others to be removed at intervals of 1 year, beginning July 1938, with view of determining if longer retention of screens is necessary because of possibility that larger rodents (e.g. rabbits and gophers) may attack older seedlings. Since sowings were made on two different sites, this experiment will also supply data on degree of success in relation to site -- especially with reference to cover.

4. Removal of Protective Screens at Different Intervals from Different Species of Seedlings.

Purpose. To determine relative susceptibility of seedlings of different species to destruction by rodents.

Procedure. Same as for (3) but slight difference in dates of sowing and screen removal. Two sites and conditions represented; namely, denuded area on west slope and partially cut mature stand of Douglas-fir-white fir on north slope. Both sites within short distance of each other. Plots representing each species adjacent.

This experiment was also repeated in 1938. Same procedure regarding future removal of screens contemplated. The results of this experiment should indicate adaptability of the respective species in relation to site and cover.

5. Different Numbers of Seeds per Spot.

<u>Purpose</u>. To determine minimum number of seeds required to insure establishment of at least one seedling per spot. To allow for possible losses there should be several seedlings per spot to begin with. On the other hand, if there are too many seedlings subsequent losses may be heavy on account of competition between seedlings.

<u>Procedure</u>. Spots sowed in July 1938, at rate of 6, 8, 10, 12, and 14 seeds per spot according to Latin square design as described under (3), on 4 different sites including (a) north slope denuded; and (b) west slope denuded and with partial cover of young pine, oak, and elder; (c) oak cover; (d) aspen cover. Spots protected by use of both cans and screens. Only Douglas-fir seed sown so far.

6. Seed Spotting versus Planting.

<u>Purpose</u>. To determine relative merits of reforesting cut-over areas by seed spotting and by planting nursery-grown stock.

<u>Procedure</u>. Three-year-old Douglas-fir seedlings were planted in the spring of 1938 between the seed spots of the Latin squares described under (3), (4), and (5).

7. Partly Germinated versus Untreated Seed, in Prepared, Unprepared, Protected and Unprotected Spots.

<u>Purpose</u>. Primarily to determine if pre-treatment of seed is of any value in hastening seedling establishment and whether the seed so treated is less likely to be found by mice. Sowings of Douglas-fir, ponderosa pine and white pine seed in protected spots, in 1937, indicated that good results can be obtained from partly germinated seed, provided that germination is not too far advanced. Best results were obtained where seed was sown immediately after bursting of the seed coat. The present experiment pertains to Douglas-fir only.

<u>Procedure</u>. To induce partial germination, seed was kept in damp peat moss for several days. This and untreated seed were then sown in adjacent spots placed 2 feet apart. Ten seeds were sown in each spot. Four of such sets of spots were sown in four parallel rows in accordance with the following treatments: (1) spots prepared and screened; (2) spots screened but not prepared; (3) spots prepared but not screened; (4) spots not prepared and not screened. Motor oil cans were placed over all of the spots. The location of the four differently treated sets of spots in each row was determined by randomized selection. Sowings were made on June 28, 1938, on five different sites.

8. Sowing of Seed in Prepared, Unprepared, Protected, and Unprotected Spots - Inside and Outside of Rodent Enclosures.

Purpose. Primarily, to determine to what extent birds are responsible for failure of seed spots. Inasmuch as it is assumed that rodents do not have access to the rodent enclosures, comparison of results obtained inside and outside of the enclosures should be indicative. Results from protected spots serve as checks.

Procedure. Spacing and selection of spot locations same as in (7). No motor oil cans placed over spots. Ten seeds sown in each spot. Sowings were made on July 9, 1938, on five different sites.

9. Testing of Different Methods of Protecting Seed Spots.

Purpose. To determine the best method of preventing the destruction of seed and seedlings by rodents and birds and other agents. As cost is an important item, the aim is to develop a cheap yet effective device for protecting seed spots.

Developments to Date. When seed spotting experiments were begun in 1935, large cone-shaped screens 9 inches in diameter at the base, made of hardware cloth, were used. Experience later showed that a screen 7 inches in diameter at the base was more suitable. In placing the screens over the seed spots, they were sunk about 1 inch below the ground line, with the view of preventing rodents from undermining them. As a further precaution, rocks were, when available, placed around the screens or against the sides. In using the latter method it was found that the rocks also helped to shade the spots, which proved to be beneficial, especially where natural shade was lacking. The screens did not, however, always prevent rodents from undermining them. Furthermore, they did not effectively prevent alluvial soil from being deposited on the spots, a condition experienced especially where sowing was done on steep slopes. The situation was remedied through the use of motor oil cans which, with the ends cut out, were sunk about two-thirds of the way into the soil, and screens fitted over them. It was later conceived that screens could just as well be placed inside of the cans rather than over them. By so doing, a material reduction in the size of screen required became possible, namely, from 7 inches x 7 inches to 4 inches by 4 inches.

Because of the drawback of having two separate units to handle, a screen was devised which incorporated the essential features of both can and screen in a single unit. In order to make a cone out of a single piece of metal, it was necessary to dispense with screen material and substitute perforations in the tin. A test of a few of these cones in the field showed that the perforated area let in sufficient light so that seedlings developed fully as well under them as under the hardware cloth screens.

The only foreseen objection to these cones is their cost, which is high. [How about temperature changes under the metal? - Ed.]

Since motor oil cans are readily available -- at no cost so far -- it was thought that instead of using hardware cloth screens to cover the top, cotton mesh fabric, such as supplied by the A.A.A., might serve the purpose. This material accordingly was tested on several hundred spots in the summer of 1938. The material was cut into pieces about 7 inches square. Some of these were fastened to the tops of the cans with wire rings and some with rubber bands. The object of using rubber bands was to see if these would eventually disintegrate. If so, the necessity of later removing the cotton mesh fabric by hand would not be necessary. The chief objection to the use of this material is that rodents can cut it. But, although this is what actually did take place on some of the sown plots, it did not occur on most of them. It was thought that the mesh of the fabric might be too fine to allow for proper development of the seedlings. The contrary, however, was found to be true, the seedlings appearing to be fully as thrifty as those in spots protected with hardware cloth screens. Presumably, the fabric reflects sufficient light to compensate for the reduction in direct sunlight. It remains to be seen what will happen to these seedlings during the ensuing winter.

Inasmuch as seed spots must be protected, it might be argued that it would be cheaper to plant nursery stock. Although this may be true, it should be remembered that planted nursery stock is susceptible to attack by larger rodents. Thus far results at the Cloudcroft Branch Station have shown that this is not generally true of seedlings that have been grown in protected seed spots and later released.

B. Broadcast Seeding.

1. Broadcast Sowing of Douglas-fir Seed in a selectively cut mature stand of Douglas-fir and White Fir in which different kinds of leaf litter were placed.

Purpose. Primarily, to determine if type of litter has any bearing on the establishment of natural reproduction. Results of sowings made from 1932-1935 in meter square quadrats inside and outside of rodent enclosures indicated that the litter of ponderosa pine and white pine was instrumental in partially protecting seed from mice and birds, in that the presence of such litter makes it difficult for them to find the seed. The vigorous growth and appearance of seedlings in the plots treated with aspen and oak litter indicated a beneficial fertilizing effect.

Procedure. To test the influence of litter on a larger scale four adjacent 1/10-acre plots were laid out in 1938 and a cover

of different kinds of leaf litter placed on the forest floor, namely, ponderosa pine, white pine, aspen, oak. A fifth untreated plot was laid out as a check. On 1/2 of each of the five, Douglas-fir seed was sown on July 11 at the rate of about 90,000 seeds per acre. As very few seedlings resulted from this sowing the plots were re-sown on October 25, this time at the rate of about 160,000 seeds per acre. The plots, together with a fairly large area surrounding them, had shortly before been thoroughly poisoned with thallium-treated sunflower seed and it is believed that rodents were thereby reduced to a minimum number. Results of sampling the sown plots next summer should indicate the relative effectiveness of the different types of litter on germination and survival.

2. Broadcast Sowing of Douglas-fir Seed in a selectively cut mature stand and different numbers of seeds per acre.

<u>Purpose</u>. To determine the relation between seed supply and resulting seedlings and also whether, in the absence of rodent control, adequate restocking can be obtained where seed supply is ample.

<u>Procedure</u>. Five adjacent 1/10-acre plots laid out in a selectively cut mature stand where site conditions appeared to be very favorable for seedling establishment. Area had been logged in fall of 1937; slash and cull material removed and burned. Logging stirred up forest floor, creating good seedbed. On half of each of the 1/10-acre plots seed was sown on July 15, 1938, at different rates per acre, namely 80,000, 160,000, 240,000, 320,000, and 400,000. Immediately after seed was sown a heavy shower of rain fell. Moisture conditions remained favorable for germination throughout the season.

Examination of the plots shortly after seed had been sown showed that rodents had been very active. Sampling of the plots in October showed very few seedlings on any of the plots.

Since this sowing was made, the area has been poisoned but no additional sowings. Sowing was done last fall. It is planned to repeat the experiment in 1939.

SUGGESTED FORM

DIRECT SEEDING

File Desig. __________

1. Admin. Unit ______________________________

2. Species used ______________________________ Location ______________

3. Date of seeding ______________________________ Acres seeded __________
   Month Year

4. Purpose ____

   ____

   ____

5. Results: Germination ____________________ Survival at end of first

   growing season ____________________ Survival __________ __________
   Date, %, No. / acre

   Condition ______________________________

6. Losses caused by ____

   ____

7. Methods: ______________________________ Ground Preparation __________
   Broadcast or spot

   ______________________________ No. seed per spot __________________

   ______________ Depth ____________________ Spacing __________________

   Tools used ____

8. Site factors

   Soil ____

   Cover (Note recency of burns) ____

   ____

   Temperature ____
   (Note normal or abnormal conditions)

Rainfall ______________________________
(Note normal or abnormal conditions; frequency & abundance)

Aspect ______________________ Slope ______________________

9. Protection given seeding:

Screens or other cover ______________________

Fenced ______________________

Repellents ______________________

Other protection ______________________

Weedings ______________________
(Dates, methods)

Cultivation ______________________
(Dates, methods)

10. Seed Source ______________________

Germination % ______________________

11. Costs ____________ Total per acre $______________________

Seed $____________ Seeding $____________ Protection $__________

12. Remarks (Include present status and recommendations) ____________

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